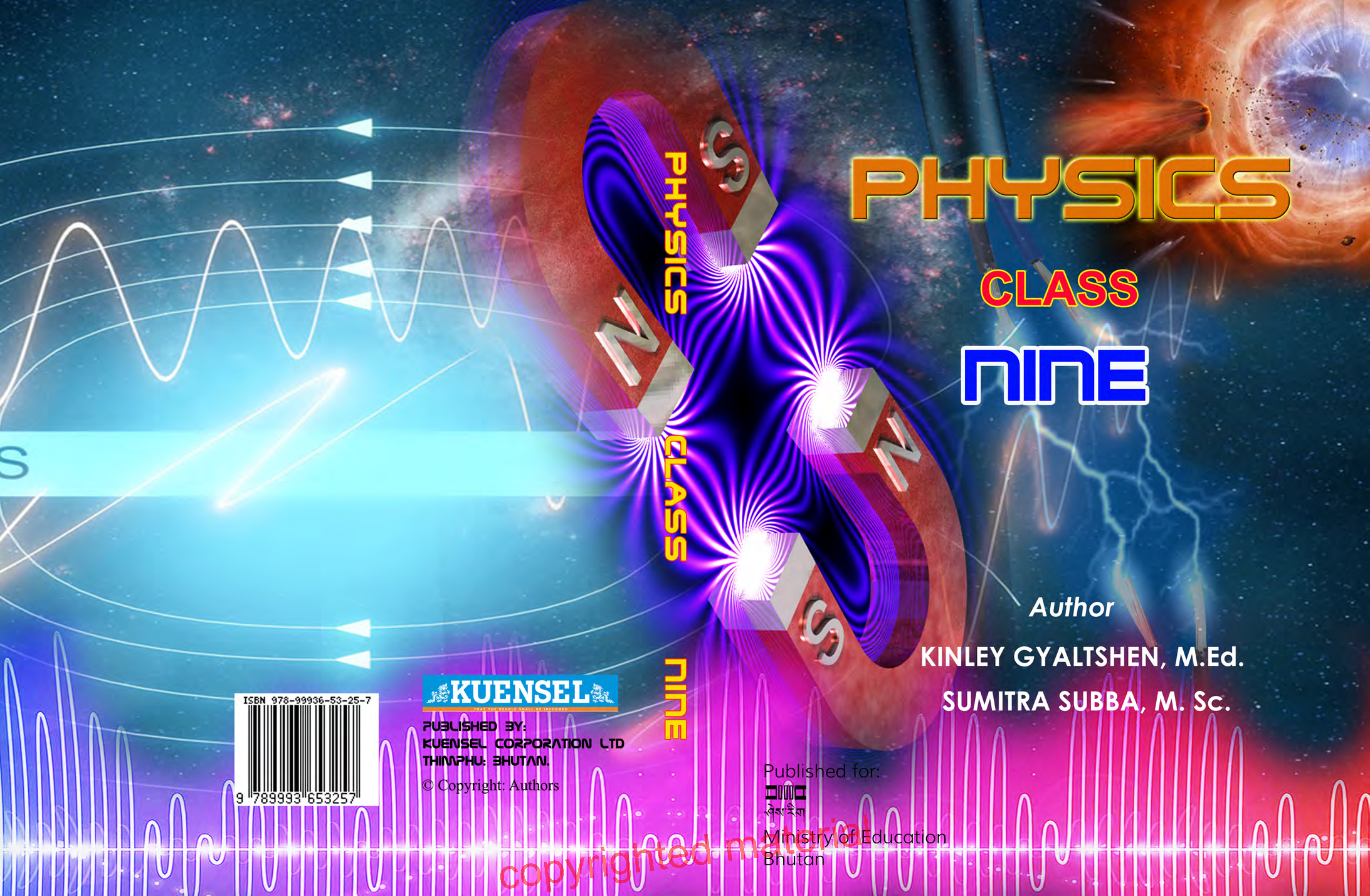
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# Physics

## Class
## Nine

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# Preface

Teaching Physics is fun and we have been doing this for more than ten years now. Students in Bhutan have been learning science in the form of Physics, Chemistry and Biology from class IX onwards. Some of the challenges in learning science are rote learning without much experimentation and lack of opportunities to test the concepts learnt. Learning of scientific knowledge, skills and values from experience and verification through right experiments becomes rational, meaningful and worthwhile.

Like other branches of science, Physics is a science of technology, energy and study of mechanics, among others. The science strives to make living comfortable and more meaningful on the Earth. Safety and security in energy resources are a concern in this modern world and scientific approaches to save these resources have become indispensable nowadays.

Science curriculum in Bhutan has undergone a change in recent years. This book is aimed to continue the building of Physics concepts and skills learnt in class IX. The special features of this textbook include competency based questions, topic end questions, relevant solved examples after topics and a model question paper at the end of the book. Utmost care has been given to introduce the new concepts by relating to the existing knowledge of the learners and befitting activities are designed to either induce or consolidate their learning. Children will have the opportunity to learn all the 21$^{st}$ century skills for learning through active learning strategies and at the same time assess their learning.

All suggestions and constructive feedbacks are welcome and we shall try our best to accommodate them in subsequent editions.

-Authors

# Syllabus

**Strand: Physical processes**

## 1. Forces and Motion

### (i) Force and acceleration

- Determine and represent distance, time and speed graphically.
- Apply equations of motions to simple numerical problems (no derivations).
- Explain momentum and state its affect on vehicle stopping distances.
- Identify the differences between speed and velocity.
- State that acceleration is change in velocity per unit time.
- Demonstrate that mass is the property of a body which resists change in motion.
- Define *the newton* as the force required to accelerate one kg of mass at a rate of $1 m/s^2$.
- Explain that balanced forces do not alter the velocity of a moving object.
- State and use the equation $F=ma$, where mass is constant, considering that force and acceleration are always in the same direction.
- Apply the kinematic equations for constant acceleration and $F=ma$ to analyse the motion of objects.
- Explain that when two bodies interact, the forces they exert on each other are equal and opposite (Newton's third law).

### (iii) Pressure

- Explain Archimedes' Principle, buoyancy, equilibrium of floating bodies, and pressure in fluids.
- Determine density of irregular solids and liquid using Archimedes' principle.

## 2. Energy

### (i) Temperature

- Convert temperatures from degrees Celsius to Kelvin and Fahrenheit, and Centigrade.
- Explain the transfer of thermal energy from a region of higher temperature

to a region of lower temperature.

- Explain thermal equilibrium.

### (ii) Energy resources and energy transfer

- Explain the use of insulation to reduce transfer of energy from hotter object to colder object.

### (iii) Thermal properties of materials

- Define specific heat capacity.
- Apply the equation $Q = mc\Delta T$ in numerical problems.
- Explain the terms latent heat of fusion and latent heat of vaporisation *(numerical problems excluded).*
- Describe and explain the thermal expansion of matter, giving examples of where it must be accounted for e.g. electric transmission lines, bridges, hot water pipes.

## 3. Electricity and magnetism

### (ii) Electromagnetic effects

- Define and explain the terms a.c. and d.c.
- Explain that a force is exerted on a current-carrying wire in a magnetic field and explain this effect in simple electric motors.
- Explain that a voltage is induced when a conductor cuts magnetic field lines and when the magnetic field through a coil changes.

### (iii) Electric charge

- Explain charging of an insulating material by friction.
- Describe the forces of attraction between unlike charges (positive and negative charges), and forces of repulsion between like charges.
- Explain electric current in terms of the flow of charge carried by free electrons in metals or ions during electrolysis.
- Calculate steady current, charge and time using the formula $I = \dfrac{dq}{dt}$ .

## 4. Waves

### (i) Characteristics of waves

- Explain dispersion and refractive index of different coloured light through a prism.

- Describe the properties of waves (reflection and refraction) including light and sound as examples of transverse and longitudinal waves.
- Define the terms time period, frequency, wavelength and amplitude of a wave.
- Calculate the speed, frequency and wavelength of a wave using the equation $v = f\lambda$.
- Explain that waves transfer energy without transferring matter.
- Explain total internal reflection and its applications e.g. in telecommunications (Optical fibres).
- Describe uses of ultrasound e.g. medical scanning, SONAR (measuring depth of ocean, human and bats) and radio waves in RADAR.

## 5. The Earth and beyond

- Describe relative positions and sizes of planets, stars and other bodies in the universe (for example, comets, meteors, galaxies, black holes, worm holes)
- Describe how the development of technology has helped our knowledge and understanding of the Solar System and the universe as a whole e.g. early telescopes, early satellites, modern space probes and space telescopes.

## Assessment

Assessment in science involves detailed process of measuring students' achievement in terms of knowledge, skills, and attitude. The progress of learning is inferred through analysis of information collected. The accuracy and objectivity of assessment determines its validity. The modality and components of assessment should be clearly conveyed to the students. The teacher's expectations should be made clear to students and appropriate learning outcomes should be set. The teachers can play an important role in the students' achievement by effectively monitoring their learning, and giving them constructive feedback on how they can improve, and provide the necessary scaffolding for the needy learners as identified through reliable assessment techniques and tools.

### Purpose of Assessment

Assessment is used to:

- **inform and guide teaching and learning:** A good assessment plan helps to gather evidences of students' learning that inform teachers' instructional decisions. It provides teachers with information about the performance of students. In addition to helping teachers formulate the next teaching steps, a good classroom assessment plan provides a road map for students. Therefore, students should have access to the assessment so they can use it to inform and guide their learning.
- **help students set learning goals:** Students need frequent opportunities to reflect on what they have learnt and how their learning can be improved. Accordingly, students can set their goals. Generally, when students are actively involved in assessing their own next learning steps and creating goals to accomplish them, they make major advances in directing their learning.
- **assign report card grades:** Grades provide parents, employers, other schools, governments, post-secondary institutions and others with summary information about students' learning and performances.
- **motivate students:** Students are motivated and confident learners when they experience progress and achievement. The evidences gathered can usher poor performers to perform better through remedial measures.

The achievements and performances of the learners in physics are assessed on the following three domains:

- **Scientific knowledge:** Basic knowledge and understanding of energy and work, force and structures, electricity and magnetism, sound and light, thermodynamics, modern physics and inter-relationship of physical science with other branches of science, and their attributes to people and environment .

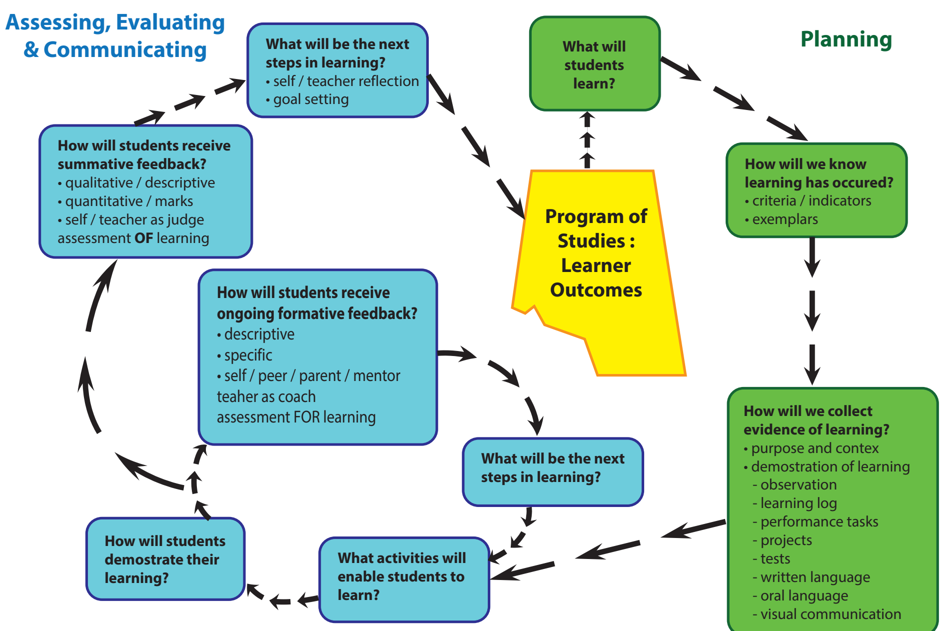
- **Working scientifically:** Basic understanding of the nature of science, and how science works. Demonstration of logical and abstract thinking and comprehension of complex situations. Explore how technological advances are related to the scientific ideas underpinning them. Compare, contrast, synthesize, question and critique the different sources of information, and communicate their ideas clearly and precisely in a variety of ways, including the use of ICT.
- **Scientific values and attitudes:** Consider the power and limitations of science in addressing social, industrial, ethical and environmental issues, and how different groups in the community and beyond may have different views about the role of science. They make informed judgments on statements and debates that have a scientific basis, and use their learning in science for planning positive action for the welfare of themselves, others in their community and the environment.

## The Assessment Process

Effective classroom assessment in Science:

- assesses specific outcomes in the program of studies.
- the intended outcomes and assessment criteria are shared with students prior to the assessment activity.

**Assessing Student Learning in Classroom**



- assesses before, during and after instruction.
- employs a variety of assessment strategies to provide evidence of students' learning.
- provides frequent and descriptive feedback to students.
- ensures students can describe their progress and achievement, and articulate what comes next in their learning.
- informs teachers and provides insight that can be used to modify instruction.

## Scheme of assessment in science

The following schemes of assessment are used to assess students' performance:

### 1. Continuous Formative Assessment (CFA)

Formative assessment is used to provide feedback to teachers and students, so that teaching and learning can be improved through the provision of regular feedback and remedial learning opportunities. It also enables teachers to understand what teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of learners and recognize the individual differences in learning. Through the constructive feedback, students are able to understand their strengths and weaknesses. It also empowers them to be self-reflective learners, who monitor and evaluate their own progress.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is NOT graded, as it is only to give continuous feedbacks to the students.

### 2. Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment (CA). It helps in determining the student's performance and the effectiveness of instructional decisions of teachers. The evidences from this assessment help students to improve learning, and mandate teachers to incorporate varied teaching strategies and resources to ensure quality teaching and learning in the science classes. This assessment also empowers students to be self-reflective learners, who monitor and evaluate their own progress.

In CSA, the students' performances and achievements are graded. This ensures active participations of learners in the teaching and learning processes.

### 3. Summative Assessment (SA)

Summative assessment (SA) is conducted at the end of the first term and at the end of the year to determine the level of learning outcomes achieved by students. The information gathered is used by teachers to grade students for promotion, and to report to parents and other stakeholders.

The identified techniques for SA are term examinations - first term and annual examinations. The questions for the term examinations should cover all the three domains of science learning objectives, using the principles of Bloom's taxonomy.

Assessment Matrix

| Types of assessment | CFA | | | CSA | | | SA | |
|---|---|---|---|---|---|---|---|---|
| Definition | It is a continuous process of assessing student's problems and learning needs and to identify the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best. | | | It is a continuous process of grading student's performances and achievements. Teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best. | | | Assesses student's cumulative performances and achievements at the end of each term. | |
| Domains | Scientific knowledge (SK) | Working scientifically (WS) | Scientific values and attitudes (SV) | Scientific knowledge (SK) | Working scientifically (WS) | Scientific values and attitudes (SV) | SK, WS & SV | SK, WS & SV |
| Techniques | Quiz & debate,class presentation, homework, class work, immediate interaction with students. | Immediate interaction with students, class work, home work, experiments, exhibition, case studies | Observation of student's conduct, in group work, field trip, excursion, etc. | Home work and chapter end test. | Practical work | Project Work. | Term exam. | Term exam |
| Assessment Tools | Q&A, checklist and anecdotal records. | Checklist and anecdotal records. | Checklist and anecdotal records. | Rubrics (HW) and paper pencil test (Chapter end test). | Rubrics (Practical work) | Rubrics (Project work) | Paper pencil test | Paper pencil test |
| Frequency interval (when &how) | Checklists and anecdotal records must be maintained for each topic throughout the academic year. | | | HW-for every chapter, Chapter end test – for every chapter. | Practical work once in each term | Project Work –Once for the whole year but assessed two times (half yearly) | Once in a term. | Once in a year. |
| Format in Progress Report | | | | SK | WS | SV | Mid-Term | Annual Exam |
| Weightings | | | | T1= 2.5<br>T2= 2.5 | T1= 5<br>T2= 5 | T1= 2.5<br>T2= 2.5 | T1=30 | T2=50 |

## Assessment Techniques and Tools

The following techniques and tools are used in assessing students' performance with objectivity.

### 1. Observation Check list

Observing students as they solve problems, model skills to others, think aloud during a sequence of activities, or interact with peers in different learning situations provides insight into student's learning and growth. The teacher finds out under what conditions success is most likely, what individual students do when they encounter difficulty, how interaction with others affects their learning and concentration, and what students need to learn next. Observations may be informal or highly structured, and incidental or scheduled over different a period in different learning contexts.
Observation checklists are tools that allow teachers to record information quickly about how students perform in relation to specific outcomes from the program of studies. Observation checklists, written in a yes/no format can be used to assist in observing student performance relative to specific criteria. They may be directed toward observations of an individual or group. These tools can also include spaces for brief comments, which provide additional information not captured in the checklist.

Tips for using Observation Checklists

i. *Determine specific outcomes to observe and assess.*

ii. *Decide what to look for. Write down criteria or evidence that indicates the student is demonstrating the outcome.*

iii. *Ensure students know and understand what the criteria are.*

iv. *Target your observation by selecting four to five students per lesson and one or two specific outcomes to observe. Date all observations.*

v. *Collect observations over a number of lessons during a reporting period and look for patterns of performance.*

vi. *Share observations with students, both individually and in a group. Make the observations specific and describe how this demonstrates or promotes thinking and learning.*

vii. *Use the information gathered from observation to enhance or modify future instruction.*

***Sample Checklist***

| Name | Topic: Pressure | | | | | | | | | Teacher's comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Scientific knowledge | | | Working scientifically | | | Scientific values | | | |
| | Explains pressure and thrust per unit area | Lists down the significance of pressure in our daily lives | State Archimede's Principle and describe its applications | Follows correct experimental procedures. | Handles equipment, apparatuses, and chemical safely. | Demonstrates ability to set up experiments. | Respects others ideas and views | Shows curiosity to learn science | Demonstrates concern for oneself and others | |
| Sonam | | | | | | | | | | |
| Tshering | | | | | | | | | | |
| | | | | | | | | | | |

## 2. Anecdotal notes

Anecdotal notes are used to record specific observations of individual student **behaviours, skills, and attitudes** in relation to the outcomes of the science teaching and learning process. Such notes provide cumulative information on students' learning and direction for further instruction. Anecdotal notes are often written as ongoing observations during the lessons, but may also be written in response to a product or performance of the students. They are generally brief, objective, and focused on specific outcomes. The notes taken during or immediately following an activity are generally the most accurate. Anecdotal notes for a particular student can be periodically shared with the student, or be shared at the student's request.

The purpose of anecdotal notes is to:

- provide information regarding a student's development over a period of time.
- provide ongoing records about individual instructional needs.
- capture observations of significant behaviours that might otherwise be lost.

***Tips for maintaining Anecdotal Notes***

i. *Keep a notebook or binder with a separate page for each student. Write the date and the student's name on each page of the notebook.*

ii. *Following the observations, notes are recorded on the page reserved for that student in the notebook.*
iii. *The pages may be divided into three columns: Date, Observation and Action Plan.*
iv. *Keep notes brief and focused (usually no more than a few sentences or phrases).*
v. *Note the context and any comments or questions for follow-up.*
vi. *Keep comments objective. Make specific comments about student strengths, especially after several observations have been recorded and a pattern has been observed.*

### 3. Project work

Project work is one of the best ways to practice the application of scientific conceptual ideas and skills. The very purpose of including project work is to provide opportunity to explore and extend their scientific knowledge and skills beyond the classroom. Students learn to organize, plan and piece together many separate ideas and information into a coherent whole. Through project work, students learn various scientific techniques and skills, including data collection, analysis, experimentation, interpretation, evaluation and drawing conclusion; and it fosters positive attitude towards science and environment.
The science curriculum mandates students to carry out project work to help them to:

i. develop scientific skills of planning, designing and making scientific artefacts, carrying out investigations, observation, analysis, synthesis, interpretation, organization and recording of information.
ii. enhance deeper understanding of social and natural environment.
iii. develop student's ability to work in group and independently.
iv. provide opportunity to explore beyond the classroom in enhancing their scientific knowledge and skills, which will contribute towards the development of positive attitudes and values towards science and environment.
v. understand how science works and the nature of scientific knowledge.
vi. develop oral and written communication skills.

Teachers can facilitate students to carry out the project work by considering the following suggested guidelines.

- Allow students to select their own project ideas and topics.
- Encourage students to be scientifically creative and productive.
- Provide a clear set of guidelines for developing and completing projects.
- Help students to locate sources of information, including workers in science-

related fields who might advise them about their projects.

- Allow students the option of presenting their finished projects to the class.
- Inform students about the general areas on which assessment may be made. For example, scientific content or concepts, originality of ideas, procedures, and the presentation.
- Advice students to contact their teacher for further assistance or consultations, for, students must be closely guided by the teacher starting from the selection of the topic, doing investigations, data collection, and analysis to writing report in a formal style.

Each student is assigned a Project Work for the academic year. The project work is assessed out of 28 marks, which should be converted out of 5 marks for the whole year. Students can share their project work findings, either in the form of class presentation or display.

At the end of the project work, every student must prepare a project work report, about 2000 to 2500 words, in the formal format, suggested in the following section. The product of the project work must be inclusive of write ups, illustrations, models, or collection of real objects.

Following are some of the useful steps that students may follow.

### 1. *Select a topic for the science project*

The first step in doing science project is selecting a topic or subject of your interest. Teachers guide students in identification and selection of the topic. The concerned teacher has to approve the topic prior to the commencement of the project work.

### 2. *Gather background information*

Gather information about your topic from books, magazine, Internet, people and companies. As you gather information, keep notes from where you got the information as reference list.

### 3. *Write your hypothesis*

Based on your gathered information, design a hypothesis, which is an educated guess in the form of a statement, about what types of things affect the system you are working with. Identifying variables is necessary before one can make a hypothesis. For example, depth of the fluid affects the fluid pressure. Develop a research question supported by a few questions to test your hypothesis. For example, how does the depth of fluid affect the pressure? Sub-questions may include, what is the fluid pressure at the same depth at different points? What is the fluid pressure as the depth increases?

### 4. *Identify variables*

The hypothesis and the research questions should guide you to identify the variables. When you think you know what variables may be involved, think about ways to change one at a time. If you change more than one at a time, you will not know what variable is causing your observation. Sometimes, variables are linked and work together to cause something. At first, try to choose variables that you think act independently of each other.

### *5. Design an experiment or observation method*

Having made the hypothesis, design an experiment to test the hypothesis and devise the method of observation. Make a systematic list of what you will do or observe to answer each question. This list is known as experimental or observational procedure. For observations or an experiment to give answers, one must have a "control". A control is a neutral "reference point" for comparison that allows you to see what changing or dependent variable does by comparing it to not changing anything. Without a control, you cannot be sure what variable causes your observations.

### *6. Write a list of material*

Make a list of materials useful to carry out your experiment or observations.

### *7. Write experiment results*

Experiments are often done in series. A series of experiments can be done by changing one variable at a time. A series of experiments are made up of separate experimental "runs". During each run, you make a measurement of how much the variable affected the system under the study. For each run, a different amount of change in the variable is used. This produces a different degree or amount of responses in the system. You measure these responses and record data in a table form. The data from the experiments and observations are considered as a "raw data" since it has not been processed or interpreted yet. When raw data is processed mathematically, for example, it becomes result.

### *8. Write a summary of the results*

Summarize what happened. This can be in the form of a table of processed numerical data, or graphs. It could also be a written statement of what occurred during experiments. It is from calculations using recorded data that tables and graphs are made. Studying tables and graphs, one can see trends or patterns that tell you how different variables cause to change the observations. Based on these trends, you can draw conclusions about the system under the study. These conclusions help to confirm or deny your original hypothesis. Often, mathematical equations can be made from graphs. These equations can help you to predict how a change will affect the system without the need to do additional experiments. Advanced levels of experimental science rely heavily on graphical and mathematical analysis of data. At this level, science becomes even more interesting and powerful.

### 9. Draw conclusions

Using the trends in your experimental data and your experimental observations, try to answer your original questions. Is your hypothesis correct? Now is the time to pull together what happened in the form of conclusion, and assess the experiments you did. Describe, how variables have affected the observations, and synthesize a general statement. For example, the pressure for the same fluid increases with the increase of depth!

### 10. Write a report on the project

Having completed all the steps of experiment and investigation with appropriate results and conclusion drawn, the last thing is to write a report. The report should start with an introduction on the topic related to your hypothesis, purpose of the study, literature review, methods used, findings, and conclude with conclusions. Do not forget to acknowledge the support provided by all individuals and organizations. Write a bibliography to show your references in any form. Such information includes the form of document, name of writer, publisher, and the year of publication.

*The Format for Project Work write-up (report) should include the following aspects:*

- The title of the project work.
- Acknowledgement: Show courtesy to thank the people and organizations for the help received.
- Table of content.
- Introduction: What is the topic about, and why was the topic chosen? hypothesis, research question.
- Background information: Scientific concepts, principles, laws and information on the topic.
- Methodology: Methods of data collection – sampling, tools used, etc; data sorting.
- Data analysis: Data tabulation, data processing, findings, etc. presented in a logical order with illustrations, photographs, and drawings where appropriate and necessary to support the findings.
- Conclusion: Reflection of the findings, learner's experiences and opinions regarding the project.
- Bibliography: List of the sources of the information.

The teacher uses the "Rubric for the Project Work" given below to assess the student's project work. Random viva voce is necessary to guide and support students' work during the course of project work.

### *Criteria for the Project Work*

| Name | Criteria | | | | | | Bibliography (4) | Total scores (28) |
|---|---|---|---|---|---|---|---|---|
| | Problem and hypothesis (4) | Background research on the hypothesis (4) | Experimental design / materials / procedure (4) | Investigation (4) | Analysis (4) | Format and editing (4) | | |
| Nima | | | | | | | | |
| Dawa | | | | | | | | |

### *Rubrics for the Project Work*

| Criteria | Scoring | | | | Total Score (28) |
|---|---|---|---|---|---|
| | 4 | 3 | 2 | 1 | |
| Problem and Hypothesis | • Problem is new, meaningful and well researched.<br>• Hypothesis is clearly stated in the "IF... THEN" format. | • Problem is not new but meaningful.<br>• Hypothesis is clearly stated. | • Problem is stated but neither new nor meaningful.<br>• Hypothesis is not clearly stated. | • Problem is not stated and<br>• Hypothesis is unclear. | |
| Background research on the hypothesis | • Research is thorough and specific.<br>• All the ideas are clearly explained. | • Research is thorough but not specific.<br>• Most ideas are explained. | • Research is not thorough and not specific.<br>• Few ideas are explained. | • Research not thorough and<br>• Ideas are not explained. | |
| Experimental design / materials / procedure | • Procedure is detailed and sequential.<br>• All materials are listed.<br>• Safety issues have been addressed. | • Procedure is detailed but not sequential.<br>• Most materials are listed.<br>• Safety issues have been addressed. | • Procedure is not detailed and not sequential.<br>• Few materials are listed.<br>• Few safety issues have been addressed. | • A few steps of procedure are listed.<br>• Materials list is absent.<br>• Safety issues are not addressed. | |

| Criteria | Scoring | | | | Total Score (28) |
|---|---|---|---|---|---|
| | 4 | 3 | 2 | 1 | |
| Investigation | • Variables have been identified, controls are appropriate and explained.<br>• Sample size is appropriate and explained.<br>• Data collected from at least 4 sources. | • Variables have been identified and controls are appropriate but not explained.<br>• Sample size is appropriate.<br>• Data collected from at least 3 sources | • Variables have somewhat been identified, controls are somewhat known.<br>• Sample size is not appropriate.<br>• Data collected from at least 2 sources. | • Missing two or more of the variables or the controls.<br>• Sample size is not considered.<br>• Data collected from only 1 source. | |
| Analysis& conclusion | • Appropriate tool used for analysis.<br>• Explanation is made for how or why the hypothesis was supported or rejected.<br>• Conclusion is supported by the data.<br>• Reflection is stated clearly. | • Appropriate tool used for analysis.<br>• Conclusions are supported by the data.<br>• Not enough explanation is made for how or why the hypothesis was supported or rejected.<br>• Reflection is stated. | • No appropriate tool used for analysis.<br>• Not enough explanation is made for how or why the hypothesis was supported or rejected.<br>• Conclusion is not appropriate.<br>• Reflection is not clear. | • No appropriate tool used for analysis.<br>• Not enough explanation is made for acceptance and rejection of hypothesis.<br>• Conclusion is absent.<br>• Reflection is not stated. | |
| Format and editing | • Correct format followed throughout.<br>• Report is free of errors in grammar, spelling or punctuation. | • Only one aspect of format is incorrectly done.<br>• Report contains a few errors in grammar, spelling, and punctuation. | • Only two aspects of format are incorrectly done.<br>• Report contains some errors in grammar, spelling, punctuation | • Three or more aspects of format are missing.<br>• Report contains many errors in grammar, spelling, and punctuation. | |

| Criteria | Scoring | | | | Total Score (28) |
|---|---|---|---|---|---|
| | 4 | 3 | 2 | 1 | |
| Bibliography | • Five or more references are cited in APA format and referenced throughout the paper and presentation. | • Three or four references are cited and referenced throughout the paper and presentation. | • One or two references are cited and referenced throughout the paper and presentation. | • No references made. | |
| | | | | TOTAL SCORE | |

## 4. Practical Work

Learning by doing is fundamental to science education. Practical work is one of the means that helps students to develop their understanding of science, appreciate that science is evidence driven and acquire hands-on skills that are essential to science learning and in their future lives. The practical work as defined by SCORE (2009a) is '*a "hands-on" learning experience which prompts thinking about the world in which we live*'.Therefore, the purposes of doing practical in science classes are to –

i. help students to gain or reinforce the understanding of scientific knowledge.
ii. develop students' understanding of the methods by which the scientific knowledge has been constructed.
iii. increase a student's competence to engage in scientific processes such as in manipulating and/or observing real objects and materials with due consideration for safety, reliability, etc.
iv. develop technical and scientific skills that improve science learning through understanding and application.
v. develop manipulative skills, knowledge of standard techniques, and the understanding of data handling.
vi. Inculcate excitement of discovery, consolidation of theory, and the general understanding of how science works.

Practical work is integral to the aspects of thinking and working scientifically in science, and must be built in as a full learning experience for students. Students are engaged in a range of practical activities to enable them to develop their understanding through interacting with apparatus, objects and observations.

The assessment of students' scientific skills and their understanding about the scientific processes through practical work is crucial in the process of science learning. To ensure the validity, assessment needs to sample a range of activities in different contexts; and reliability is ensured through the appropriate moderation procedures so that fairness in assessment is maintained.

The new science curriculum envisages that students are given the opportunity to undertake work in which they make their own decisions. They should be assessed on their ability to plan, observe, record, analyze, communicate and evaluate their works.

To ensure that the assessment in the practical is evidence-based and objective, rubrics is used. The rubrics are scored out of 16, which must be reduced to 5% each for the two terms.

***Criteria for the Practical Work***

| Name | Criteria | | | | Total scores (16) |
|---|---|---|---|---|---|
| | Scientific operation & report format (4) | Results & data representation (4) | Analysis & discussion (4) | Conclusions (4) | |
| Sonam | | | | | |
| Wangmo | | | | | |
| | | | | | |

## *Rubrics for the Practical Work*

| Criteria | Scoring | | | | Total Score (16) |
|---|---|---|---|---|---|
| | 4 (Very good) | 3 (Good) | 2 (Fair) | 1 (Poor) | |
| Scientific operation | • Purpose is clear purposeful.<br>• All the procedures are followed systematically.<br>• Full attention is given to relevant safety for oneself and others. | • Purpose is clear purposeful.<br>• All the procedures are followed but not done systematically.<br>• Work is carried out with some attention to relevant safety procedures. | • Purpose is inaccurate, general or extraneous.<br>• A few procedures are skipped.<br>• Safety procedures were frequently ignored | • Purpose is vague or inaccurate.<br>• Procedures are not followed<br>• Safety procedures are ignored completely. | |

| | | | | | |
|---|---|---|---|---|---|
| Results & data representation | • Representation of the data/ results in tables and graphs with correct units of measurement.<br>• Transformations in the results/data are evident.<br>• Graphs and tables are scaled correctly, with appropriate titles and labels. | • Representation of the data/results in tables and graphs with some error in units of measurement.<br>• Transformations in some of the results/ data are evident.<br>• Graphs and tables are scaled correctly with appropriate titles but no labels. | • Representation of the data/results in tables and graphs numerous error in units of measurement.<br>• Transformations in most of the results/ data are not evident.<br>• Graphs and tables are scaled correctly, but without appropriate titles and labels. | • Representation of the data/ results in tables and graphs are not relevant.<br>• Transformations in the results/ data are not evident.<br>• Some attempts are evident to produce graphs from the data/ results. | |
| Analysis & discussion | • All the tools used for analysis are appropriate.<br>• A comprehensive discussion, containing a comparative analysis is evident.<br>• The experimental findings are significant to the purpose of the experiment. | • Most of the tools used for analysis are appropriate.<br>• A comprehensive discussion, containing some comparative analysis is evident.<br>• The experimental findings do not have strong significance to the purpose of the experiment. | • Only a few tools are used for analysis.<br>• A comprehensive discussion, containing a few comparative analysis is evident.<br>• The experimental findings have weak significance to the purpose of the experiment. | • No appropriate tools are used for analysis.<br>• Comprehensive discussion is absent.<br>• The experimental findings have no significance to the purpose of the experiment. | |
| Conclusions | • Conclusions are drawn from the findings and are significant to objectives of the experiment.<br>• Limitations of experiment are identified, and ways to improve are evident. | • Conclusions are drawn from the findings but less significant to objectives of the experiment.<br>• Limitations of experiment are identified. | • Conclusions are not drawn from the findings and have no significance to objectives of the experiment.<br>• Some limitations of experiment are identified. | • No valid conclusions drawn from the findings.<br>• Limitations of experiment are not identified. | |
| | | | | TOTAL SCORE | |

### *Chapter-wise Weighting and Time allocation*

| Chapters | Chapter title | Maximum time required (mins) | Weighting (%) |
|---|---|---|---|
| Chapter 0 | Introduction to Physics | 90 | 0% |
| Chapter 1 | Forces and Motion | 677 | 16% |
| Chapter 2 | Pressure in Fluids | 635 | 15% |
| Chapter 3 | Energy | 888 | 21% |
| Chapter 4 | Electricity and Magnetism | 677 | 16% |
| Chapter 5 | Refraction and Dispersion of Light | 508 | 12% |
| Chapter 6 | Waves | 508 | 12% |
| Chapter 7 | The Earth and Beyond | 338 | 8% |
| | Total | 4320 | 100% |

*The total time required to complete the topics is 4320 minutes or 96 periods of 45 minutes in a period.*

# CONTENTS

0

# Introduction to Physics

## 1. What is Physics?

The word 'physics' comes from the Greek word 'phusis' which means 'nature'.

Man has always been curious to know about nature and the laws governing it. Physics reveals these basic laws from day-to-day observations.

Physics is a branch of science that deals with the natural phenomena taking place in the universe, the properties and structure of matter, and the laws governing the motion of matter. Physics is a quantitative science, and its fundamental laws are formulated in mathematical language. Physics studies everyday phenomenon and it is also often described as the study of matter and energy.

## 2. Scope of Physics

The scope of physics is very wide. It deals with a wide variety of disciplines like heat, light, energy, electricity, magnetism, electronics, etc. Physics can help us understand just about everything in the world around us. Physics helps to develop skills which are essential for pursuing higher studies and prepare the students for a variety of occupations. Physics also makes significant contributions through advances in new technologies that arise from theoretical breakthroughs. For example, advances in the understanding of electromagnetism or nuclear physics led directly to the development of new products that have dramatically transformed modern-day society, such as television, computers, mobile phones, domestic appliances, and nuclear weapons; advances in thermodynamics led to the development of industrialization and innovation, and advances in mechanics inspired the development of calculus.

Physicists may be roughly divided into two camps: experimental physicists and theoretical physicists.

Experimental physicists design and run careful investigations on a broad range of

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phenomena in nature, often under conditions which are atypical of our everyday lives. They may, for example, investigate what happens to the electrical properties of materials at temperatures very near absolute zero or measure the characteristics of energy emitted by very hot gases.

Theoretical physicists propose and develop models and theories to explain mathematically the results of experimental observations. Experiment and theory therefore have a broad overlap.

Accordingly, an experimental physicist remains keenly aware of the current theoretical work in his or her field, while the theoretical physicist must know the experimenter's results and the context in which the results need to be interpreted.

## 3. Branches of Physics

Physics is a very broad and complex subject. It is usually distinguished into classical physics and modern physics. Classical physics has its origins approximately four hundred years ago in the studies of Galileo and Newton on mechanics, and similarly, in the work of Ampere, Faraday, Maxwell and Oersted one hundred fifty years ago in the fields of electricity and magnetism. This physics handles objects which are neither too large nor too small, which move at relatively slow speeds.

The emergence of modern physics at the beginning of the twentieth century was marked by three achievements. The first, in 1905, was Einstein's brilliant model of light as a stream of particles (photons). The second, which followed a few months later, was his revolutionary theory of relativity which described objects moving at speeds close to the speed of light. The third breakthrough came in 1910 with Rutherford's discovery of the nucleus of the atom. Rutherford's work was followed by Bohr's model of the atom, which in turn stimulated the work of de Broglie, Heisenberg, Schroedinger, Born, Pauli, Dirac and others on the quantum theory. The avalanche of exciting discoveries in modern physics continues today.

Given these distinctions within the field of Physics experimental and theoretical, classical and modern, it is useful to further subdivide physics into various disciplines, including astrophysics, atomic and molecular physics, biophysics, solid state physics, optical and laser physics, fluid and plasma physics, nuclear physics, and particle physics.

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Some common branches are given below:

### i. Astrophysics

Astrophysics is the study of stars and galaxies. Astrophysics also involves abstract concepts such as predictions about the beginnings of the universe, big bang theory, black hole, cosmic background radiation, cosmic string, cosmos, dark energy, dark matter, galaxy, gravity, gravitational radiation, gravitational singularity, planet, solar system, star and supernova.

### ii. Biophysics

This branch studies the physics of living organisms. It is sometimes considered to be an overlap of biology and physics. Biophysics and medicine go hand in hand, as this study plays a big part in the development of life-saving machines and artificial limbs. It also has broader uses in engineering; everything from cars to sneakers is influenced by our understanding of biophysics.

### iii. Chemical Physics

This branch of physics involves the principles and theories of physics to study chemical processes. It is very similar to physical chemistry and has significant overlap with it. The development of batteries, fuels, medicines and building materials all result from the work people do in chemical physics.

### iv. Condensed Matter Physics

The field of condensed matter physics explores the macroscopic and microscopic properties of matter. Condensed Matter physicists study how matter arises from a large number of interacting atoms and electrons, and what physical properties it has as a result of these interactions. Designers of manufacturing equipment rely on condensed matter physics, as do people inventing new fuel sources and batteries. Breakthroughs in the field of condensed matter physics have led to the discovery and use of liquid crystals, modern plastic and composite materials.

### v. Atomic Physics

This branch of physics studies atoms and the structure of atoms. Nuclear power plants, X-ray machines and the smoke detectors in your home all exist because of our understanding of atomic physics.

Nanotechnology is a blanket term which includes large number of methods which

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scientists have developed toward the goal of manipulating matter at an atomic and sub-atomic level. Nanoscience specifically refers to the study of objects that are very tiny and are in the range of ten to hundreds of nanometers. Nanotechnology, on the other hand, is the actual manipulation, application, and use of nanometer-sized objects and matter to produce different phenomena, or for specific technologies and applications. Countless medical applications is based on nanotechnology including some that help fight cancer, and sporting equipment today are often built using nanotubes of carbon molecules which greatly enhance both strength and performance.

### vi. Molecular Physics

Unlike atomic physics, molecular physics deals with the entire molecules and the atoms that form them. By learning how to manipulate the elements, we can create new types of substances, ranging from durable metals to plastics and gels, that get used in many different industries.

### vii. Optical Physics

This branch of physics is concerned with the properties and behavior of light. It has applications in mechanics and computer engineering, as well as the use of lasers. It is also significantly playing the role in lightning technology.

### viii. Particle Physics

This is the study of subatomic particles, and how those particles interact. This is mostly a theoretical, research-based form of physics that seeks to unlock how the universe was formed and how energy is created and used.

### ix. Quantum Physics

Another mostly theoretical science, quantum physics studies physical systems using quantum theory. Related very closely to particle physics, quantum physics examines the behavior of the tiniest subatomic particles in an attempt to create general theories about physical laws.

### x. Thermodynamics

This is the branch of physics that studies heat and its relationship with other forms of energy. Like molecular physics, there are thousands of applications for this research, ranging from manufacturing to new forms of energy.

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### *xi. Mechanics.*

It is a branch of physics which deals with the properties of matter, bodies in motion and causes of motion. It may also be divided into statics, kinematics and dynamics. Statics deals with the study of forces on a body or bodies at rest. Kinematics deals with the study of motion without regard to its causes. Dynamics deals with the study of motion and the forces that affect it.

Which branch of physics sounds like the most fun to you? Whether you want to learn more about space, develop a renewable source of fuel or simply create the most comfortable sneakers ever, there's a branch of physics that can help you achieve your goal.

## 4. Methods in Physics

The knowledge of science is acquired through systematic methods consisting of the following four steps:

1. observation of facts.
2. proposing theory or hypothesis to explain the observation.
3. testing the validity of the hypothesis.
4. modification of the theory, if necessary.

For example, when we first observe events like day and night, change of seasons, phases of moon, etc, in the nature then we think of some possible explanations about these events based on certain assumptions made by us. This assumption is called "hypothesis". Then we test this hypothesis through experimentation. If it is verified then it will be called as "theory" or it fails we think of some other explanations.

Demonstration, as a teaching method in Physics teaching process leads to significantly better results when it follows scientific stages: hypothesising, discussing, experimenting and drawing conclusion. The results imply better general and conceptual understanding of basic physical concepts and measures. On the other hand, these results are extremely low when demonstration is conducted in a traditional manner, in which a student is only a passive observer and knowledge recipient, and the sole purpose of an experiment is for students to perceive a certain phenomenon. Therefore, demonstration in the physics teaching process should help students to: (a) confirm or refute their hypotheses, (b) gather relevant information, (c) draw conclusions, not having just an entertaining lesson which interrupts usually boring topics (Di Stefano, 1996). This research has shown greater

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efficiency of a modern demonstration compared to a traditional demonstration. Modern demonstration, although slightly more time-consuming, leads to higher achievement and better results.

## 5. Physics and the society

In today's world, technology has become important and indispensable part of our life. It has changed the living standard of the society. Some common applications of physics are given below:

1. The various modes of transportation like vehicles, aircrafts, rockets, etc., are manufactured based on the laws of physics.
2. The electric bulbs, electric heaters and electric fans are based on the conversion of electrical energy to other forms of energy.
3. The instruments like stethoscope, CT scan, MRI, X-ray machines etc., used in hospitals have become important tools for the doctors for easy and faster diagnosis of diseases.
4. The electric motors which are used in various electrical appliances is based on the principles of physics.
5. The dynamos which play important role in the generation of power work on the principle of electromagnetic induction.
6. The various means of communication like telephones, mobile phones, internet, etc, function due to the transmission of radio waves.
7. Digital technology also depends on the laws of physics.

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# 1

# Forces and Motion

Forces are physical agents that make objects to undergo certain changes in movement, direction, or shape and size. Stationary objects generally move under the influence of forces. Moving objects either increase or decrease their velocities, change direction or both under the influence of force.

Sir Isaac Newton studied the effects of forces on the state of bodies and formulated generalizations which are known as Newton's laws of motion.

The relationship between the speed, velocity, acceleration and their parameters provide information about the motion of bodies. A branch of science that deals with the study of moving bodies is called *Kinematics*.

## 1. Force and Acceleration

**Learning Objectives**

On completion of this topic, you should be able to:

- state the differences between speed and velocity.
- explain distance, time and speed graphically.
- define acceleration.

### A. Speed and Velocity

**Activity 1.1** **Comparing speed and velocity**

**Procedure**

**Step 1** ☞ Figure 1.1 displays various thoughts on speed and velocity.

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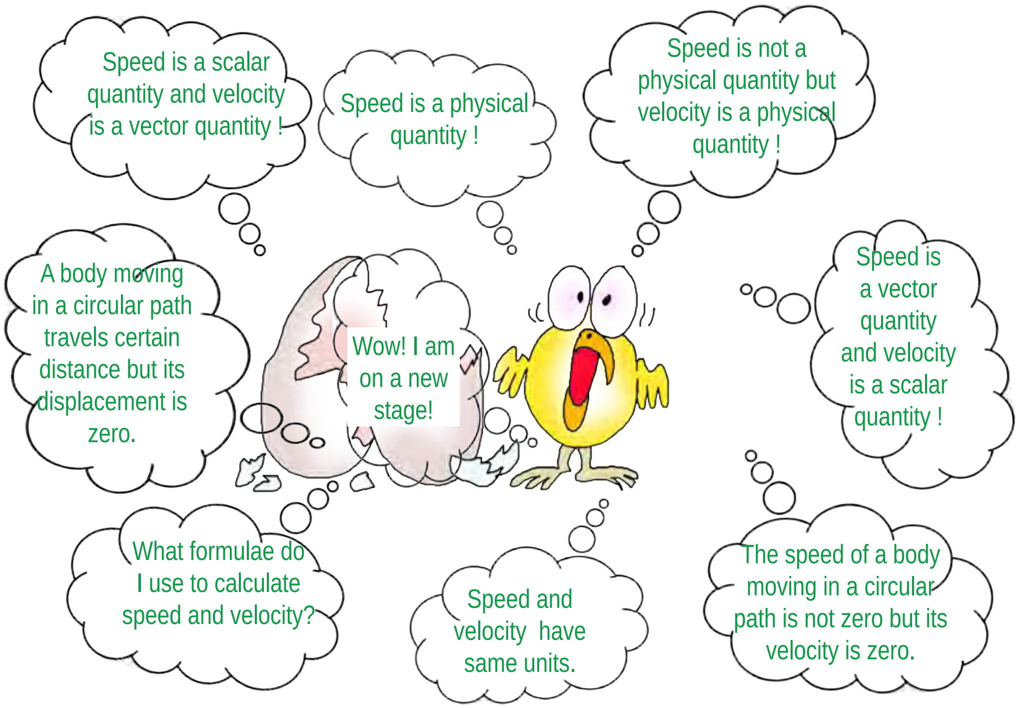


***Figure 1.1***

**Step 2** In groups, help the chick to write down the comparisons between speed and velocity, as outlined in the Table 1.1.

**Table 1.1**

| Speed | Velocity |
|---|---|
| Speed is the …………….travelled by a body in a given time period. | Velocity is………………………………….. |
| It has only ………………….., so it is called a …………….quantity. | It is a vector quantity, having both ……………………and……………………… |
| Its unit is $ms^{-1}$. | Its unit is ………… |
| Speed is calculated using the formula<br>= distance/(time ) | The formula to find out velocity of a moving body is<br>= displacement/(time ) |

**Step 3** Present your discussion and outcomes to the whole class.

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## B. Graphical representation of distance-time graphs

When an unbalanced force is applied on a rigid body, then the body moves either in a circular path or in a straight line. The movement of a body in a circular or curved path is called curvilinear motion. Similarly, the movement of a body in a straight line is called rectilinear motion.

Motion of bodies can be explained in terms of speed, velocity and acceleration. All these three physical quantities are governed by the values of distance and time. So distance-time graphs are necessary in order to have an idea about the motion of bodies.

### *i. Distance – Time Graph*

A moving body travels certain distance with the passage of time. Figure 1.2 shows how such a motion is represented by a distance-time graph. Usually, distance travelled is taken on the Y-axis and time for the journey is taken on X-axis in such graphs. From the graph, it is clear that, in every time interval of 1 s, the distance covered is 2 m, that is, equal distances are covered by the body in equal intervals of time.

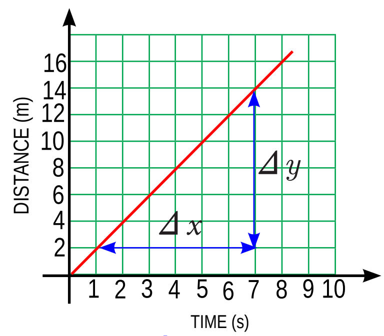

**Figure 1.2**

The speed is calculated by the formula

$$Speed = \frac{Distance}{Time}$$

$$i.e,\ Speed = \frac{Distance\ covered\ in\ y\text{ - }axis}{Time\ elapsed\ in\ x\text{ - }axis}$$

$$or\ Speed = \frac{\Delta y}{\Delta x} = slope\ of\ straight\ line\ graph$$

$$Slope = \frac{(14 - 2)}{(8 - 2)} = \frac{12}{6} = 2$$

$$\therefore Speed = 2\ m/s$$

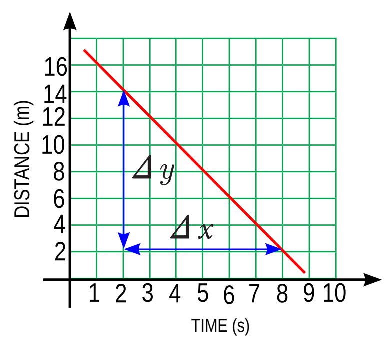

**Figure 1.3**

Therefore, the slope of the straight line in a distance – time graph (linear graph) indicates the speed of the moving body. In Figure 1.2, the slope of the graph is uniform and positive, which represents that the body moves away from the initial point with uniform speed throughout the journey. The steeper the graph, greater is the slope which indicates that the speed of the moving body is higher.

If the slope of the graph is negative as given in Figure 1.3, then it shows that the body is approaching the observer with a constant speed.

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$$Speed = \frac{\Delta y}{\Delta x} = slope\ of\ straight\ line\ graph$$

$$Slope = \frac{(2-14)}{(8-2)} = \frac{-12}{6} = -2$$

$\therefore Speed = -2\ m/s$

For a stationary body, the position of the body remains same with the passage of time. Therefore, the distance-time graph is parallel to the X-axis, as shown in the Figure 1.4.

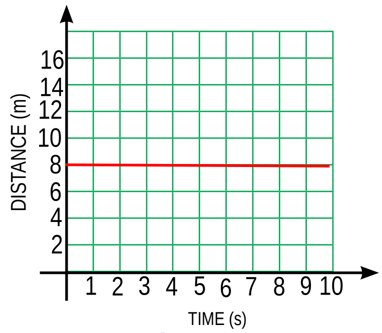

Figure 1.4

## *Some deductions from distance-time graphs*

- When the graph is a straight line parallel to X-axis, the slope is zero, then the body is stationary.
- When the slope is positive, the body is moving away from the initial point, and when the slope is negative, the body is moving towards the initial point.
- The larger the slope of the graph, greater is the speed of the body.
- When the slope is variable, the speed of the body is also variable.
- If a graph is parallel to Y-axis (distance axis), it means infinite distance is covered without any change in time interval, which is not possible.

**Example 1.1**

Sonam Wangmo drove 320 km from her home to Gangtey Goenpa. The travel graph

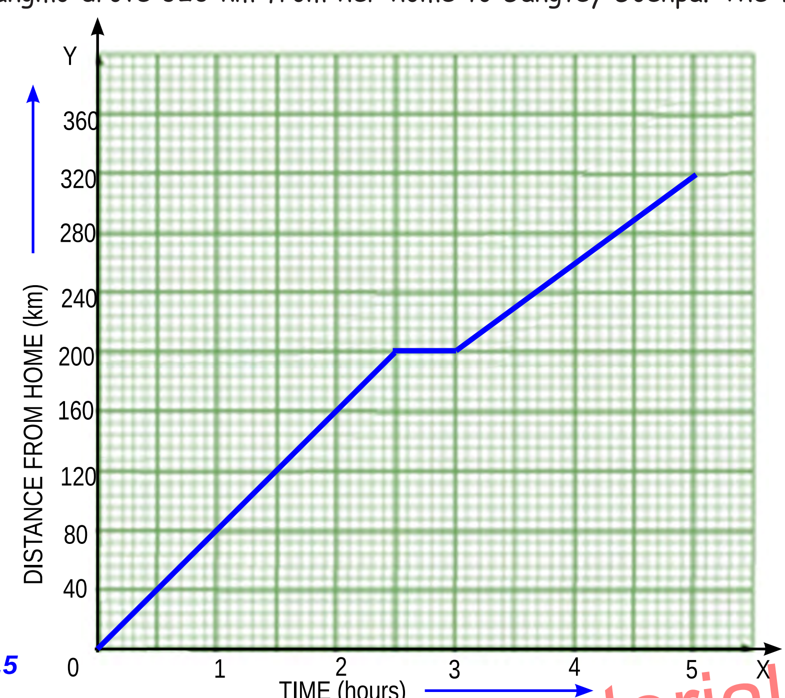

Figure 1.5

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shows her journey in Figure 1.5. During the journey, Sonam Wangmo stopped for tea and snacks.

Answer the following questions.

1. For how long did Sonam Wangmo stop for tea and snacks?

**Solution:**

*For 30 minutes.*

2. How far had Sonam Wangmo travelled in the first 90 minutes?

**Solution:**

*120 km*

3. Work out the steady speed that Sonam Wangmo travelled at after lunch.

**Solution:**

$$Speed = \frac{Distance}{Time} = \frac{120\ km}{2\ hr}$$

$$\therefore Speed = 60\ km/hr$$

4. If Sonam Wangmo's car consumes 1 litre of petrol to travel 40 km then what is total cost of petrol for Sonam's whole journey? (cost of petrol is Nu 70.00 per litre)

**Solution:**

*For 40 km, 1 litre of petrol is used.*

*For 320 km, let 'x' litre of petrol be used.*

$$x = \frac{320\ km}{40\ km} \times 1\ litre = 8\ litre$$

*Now, the cost of 1 litre of petrol is Nu 70.00*

*So, the cost of 8 litre of petrol is = 70.00 × 8 = Nu 560.00*

## Activity 1.2 Interpreting a distance-time graph

### Procedure

**Step 1** Work in groups. Study the graph 'Sherab's journey to School' in Figure 1.6. Discuss your answers with your friends. Give reasons for your answers.

**Step 2** Prepare a group response on this, for presentation to the whole class.

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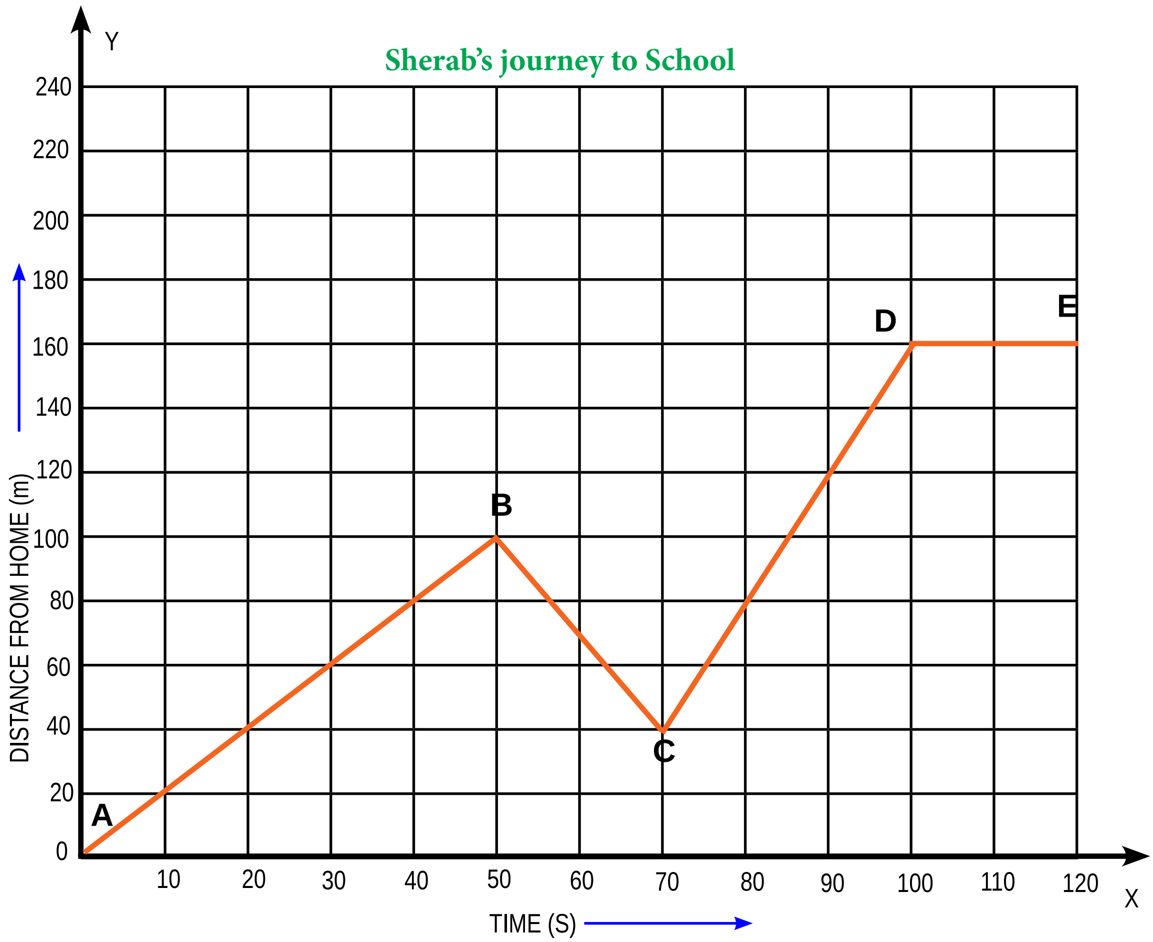


*Figure 1.6*

**Step 3** Look at the possible answers for the task, put up on the board. Read each one carefully and compare with your group responses. Refine your presentation and make it ready.

**Step 4** Present the work group wise. When all the groups have presented, compare them and have a whole class panel discussion.

**Step 5** Put up the correct presentation and discuss and find out how close are your interpretations with the model one.

Answer the following questions.

1. How far had Sherab travelled in the first 50 s?
2. How far is Sherab's school from his home?
3. How long Sherab took to reach school. Do you think he would have taken lesser time? Explain.
4. Describe the whole journey. The description should include details like how fast he walked during the different phases of his journey. The phases of the journey are marked as section AB, BC, CD and DE of the graph.

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### ii. Velocity-Time Graph

Speed in a specific direction is known as velocity. Change in velocity over a period of time is plotted by taking time on the X-axis and velocity on the Y-axis. The slope of a velocity-time graph represents acceleration. Acceleration is the rate of change of velocity.

That is,

$$acceleration = \frac{change\ in\ velocity}{time\ taken}$$

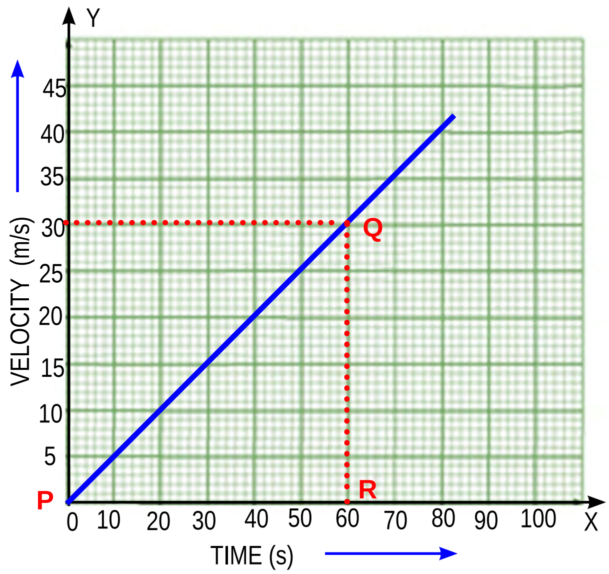


*Figure 1.7*

If initial velocity is represented by 'u', final velocity by 'v' and time taken by 't' then,

$$acceleration = \frac{final\ velocity\,(v) - initial\ velocity\,(u)}{time\ taken}$$

$$a = \frac{v\ (m/s) - u\ (m/s)}{t\ (s)}$$

$$a = \frac{v-u}{t}(m/s^2) \quad ..........\ equation\ 1$$

From the equation number 1, it is evident that the unit of acceleration is $ms^{-2}$.

A graph in Figure 1.7 shows a graph of a moving body in which velocity is increasing uniformly at 5 $ms^{-1}$ in every 10 s, that is, increase in velocity is same in equal intervals of time. The graph obtained is a straight line, and the slope indicates the acceleration of the moving body. The distance travelled by the moving body is calculated by finding the area under the graph PQ. Therefore,

$$Distance\ covered = Area\ of\ the\ triangle\ PQR$$

$$= \frac{1}{2} \times base \times height = \frac{1}{2} \times PR \times QR$$

$$= \frac{1}{2} \times 60\ s \times 30\ m/s\ (\ cancelling\ the\ units, s \times \frac{m}{s} = m)$$

$$= \frac{1}{2} \times 60\ \times 30\ m = 900\ m$$

So, the distance covered by the moving body at the end of 60 s is 900 m.

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In velocity-time graphs, the distance travelled is the area of the geometrical figure encompassed under the graph. The area of most of the shapes can be calculated by applying the corresponding mathematical formulae.

### *Generalizations from the velocity-time graphs*

- The slope of velocity-time graph indicates the acceleration of the moving body. If the slope is negative it indicates negative acceleration, or deceleration, or retardation.
- The area under the graph represents the total distance covered by the moving body.
- If the slope of the straight line graph parallel to X-axis is zero, it means that there is no change in the velocity of the moving body. Hence, the body does not undergo any acceleration.
- A straight line graph inclined at an angle of $45^0$ to the X-axis shows that the body is increasing its velocity uniformly.
- If the velocity-time graph is a curve, it indicates that the velocity changes inconsistently with time, that is, it is undergoing variable acceleration.

**Example 1.2**

Figure 1.8 shows the velocity-time graph for a car travelling in a straight line along a road.

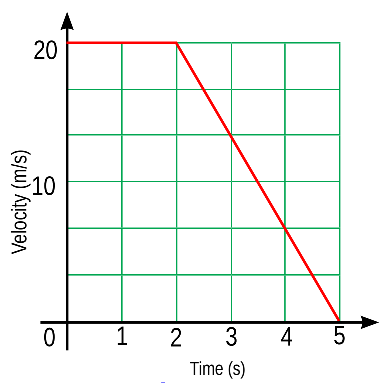


**Figure 1.8**

(a) Calculate the acceleration between t = 0 s and t = 2.0 s.

**Solution:**

$$a = \frac{v - u}{t} (m/s^2) = \frac{20 - 20}{2} = 0\ m/s^2$$

(b) Calculate the acceleration between t = 2.0 s and t = 5.0 s.

**Solution:**

$$a = \frac{v - u}{t} (m/s^2) = \frac{0 - 20}{3} = -6.67\ m/s^2$$

*The negative sign shows that the body undergoes negative acceleration. In other words, we say that the body is undergoing deceleration or retardation.*

(c) Calculate the displacement between t = 0 s and t = 5.0 s.

**Solution:**

*The displacement is the area under the graph.*

*The area is the trapezium.*

$$Area = \frac{1}{2} \times \text{height} \times \text{sum of two parallel sides}$$

$$= \frac{1}{2} \times 20 \times (2 + 5) = 70\ m^2$$

## Activity 1.3 Learning more about velocity-time graphs

Materials required:

Six worksheets A, B, C, D, E and F, chart paper, marker.

### Procedure

**Step 1** ☞ Divide the class into six groups and provide a worksheet in each group.

**Step 2** ☞ Discuss and answer the questions in respective groups. Prepare a presentation for the whole class penal discussion.

**Step 3** ☞ Put up a chart paper on the wall and title it as “Learning from velocity-time graph”.

**Step 4** ☞ Present your group in turn. After each presentation, have a panel discussion. Jot down any important points or generalization regarding velocity-time graphs, on the chart paper titled “Learning from velocity-time graph”.

**Step 5** ☞ When all the presentations are done, read the points on the chart together. Validate your learning with the help of the teacher. Keep the chart for future reference.

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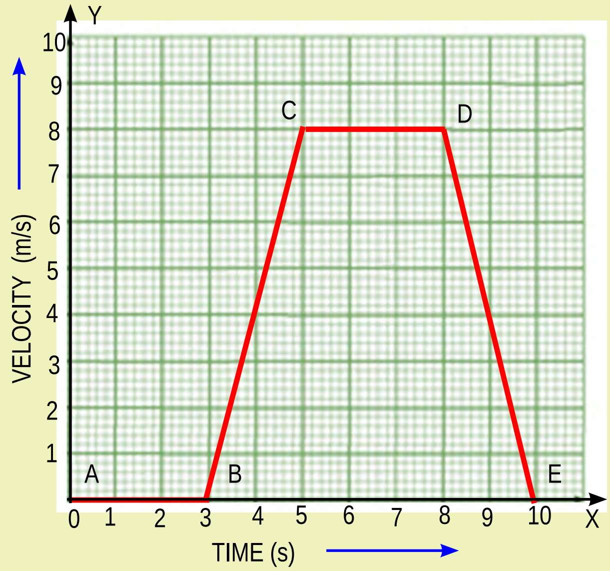
## Worksheet A

***Instructions***: Study the velocity-time graph given, and answer the following questions.

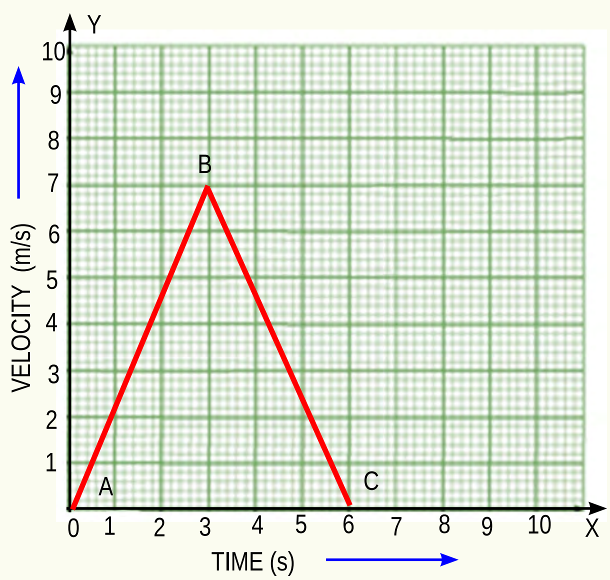
1. What information is conveyed by the part AB of the graph, regarding the velocity of body?
2. At what time does the body start to move?
3. What is the velocity of the body at 5 s?
4. Compare the part AB and CD of the graph?
5. Calculate the total distance travelled.
6. Briefly describe the whole motion.




## Worksheet B

***Instructions***: Study the velocity-time graph given, and answer the following questions.

1. What information does the part AB and BC of the graph convey regarding the change in velocity?
2. What is the maximum velocity reached?
3. What is the time required to reach the highest velocity?
4. Calculate the total distance travelled.
5. Briefly describe the whole motion.

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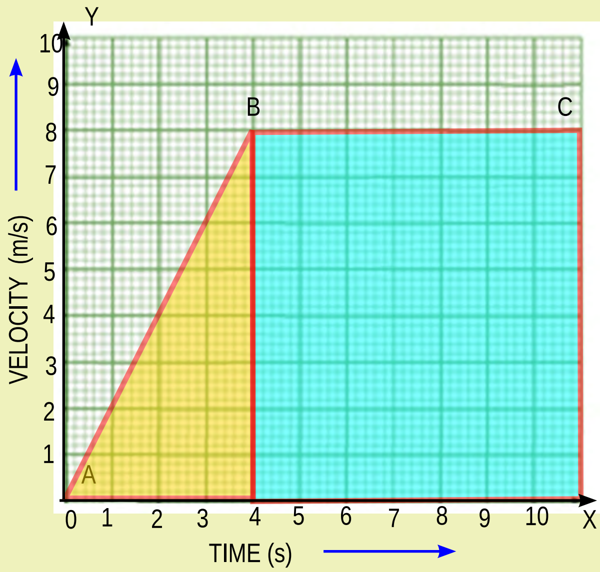
## Worksheet C

***Instructions***: Study the velocity-time graph given, and answer the following questions.

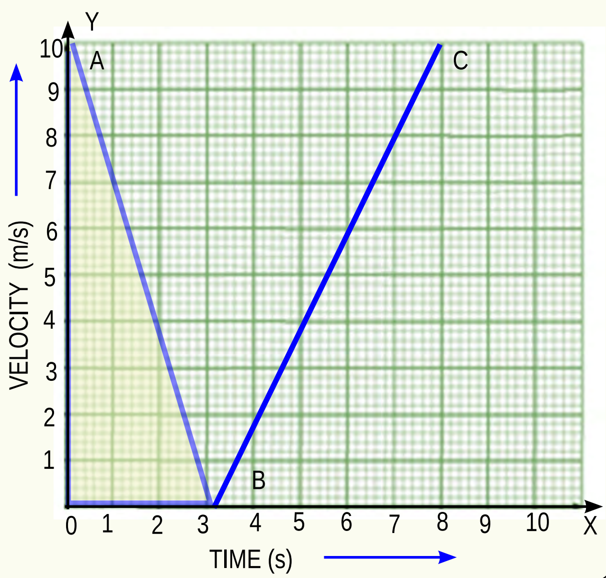
1. What information does the part AB and BC of the graph convey regarding the velocity?
2. What is the maximum velocity reached?
3. What is the time required to reach the highest velocity?
4. Calculate the total distance travelled.
5. Briefly describe the whole motion.




## Worksheet D

***Instructions***: Study the velocity-time graph given, and answer the following questions.

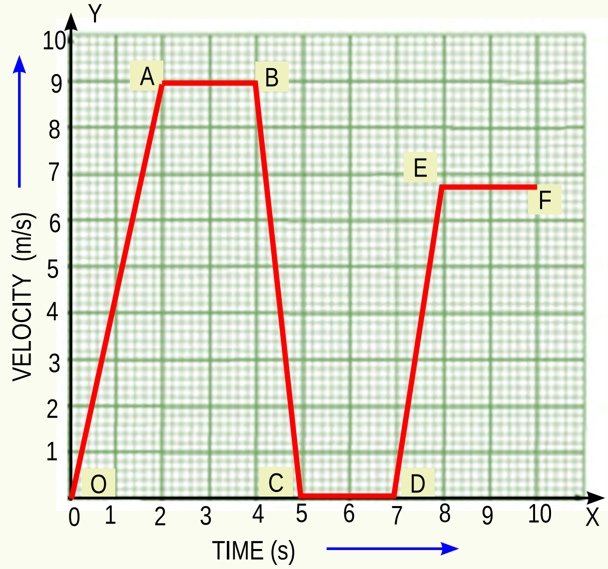
1. What information does the part AB and BC of the graph convey regarding the velocity?
2. At what time is the body coming to a halt?
3. Calculate the total distance travelled.
4. Describe such a motion from every day experience.
5. Briefly describe the whole motion.



## Worksheet E

***Instructions***: Study the velocity-time graph given, and answer the following questions.

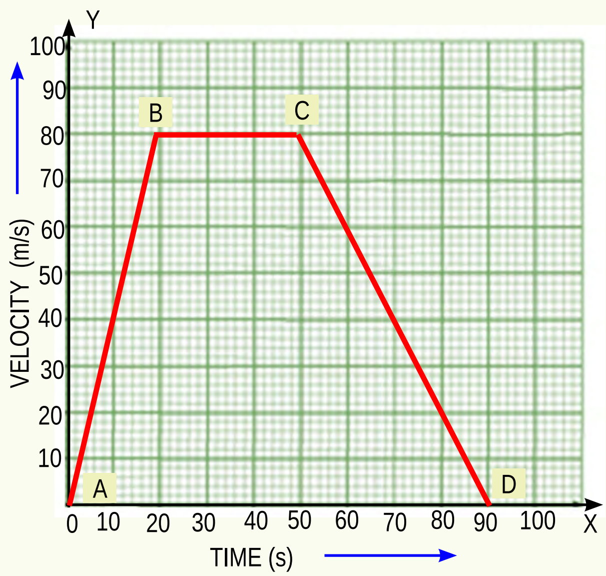
1. What information does the part AB and CD of the graph convey regarding the velocity?
2. How long does the body come to halt in the middle of the journey?
3. How many times does the body undergo acceleration? How do you know this?
4. Which part of the graph indicates that the body is undergoing deceleration, i.e. its velocity is decreasing?
5. Calculate the total distance travelled.
6. Briefly describe the whole motion.




## Worksheet F

***Instructions***: Study the velocity-time graph given, and answer the following questions.

1. What information does the part AB, BC and CD of the graph convey regarding the velocity?
2. Compare the time taken for acceleration and negative acceleration, i.e. decrease in velocity?
3. Calculate the total distance travelled.
4. Briefly describe the whole motion.

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## Questions

1. Graph in Figure 1.9 shows how Sherab, Yonten and Jamtsho ran a 100 metres dash during an Annual School Sports Day.
   a. Who won the race? Explain your answer.
   b. Who stopped for a rest? Explain your answer.
   c. How long was the rest? Explain your answer.
   d. What is the time taken by runner-up in the race?
   e. Calculate the average speed of Jamtsho.

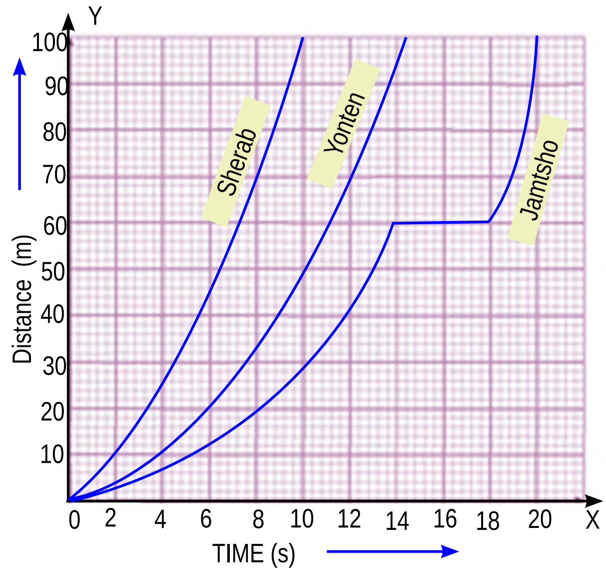

*Figure 1.9*

2. A van increases its velocity from 2.0 m/s to 10.0 m/s in 3.0 seconds. What is the van's acceleration?
3. A rolling ball slows down from 24 m/s to 15 m/s in 12 seconds. What is the ball's acceleration? Explain the meaning of negative sign in such a case.
4. Tshering rides a bike along a straight highway. The following table gives the velocity of his bike at various intervals of time:

| **Time(s)** | 0 | 5 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|---|
| **Velocity ($ms^{-1}$)** | 5 | 10 | 15 | 20 | 25 | 30 |

Now, answer the following questions:

(i) Draw a velocity-time graph for the above motion.

(ii) Calculate the acceleration of the bike.

(iii) What is the total distance travelled by Tshering at the end of the journey?

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# 2. Momentum

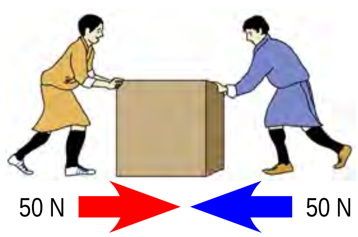
## Learning Objectives

On completion of this topic, you should be able to:

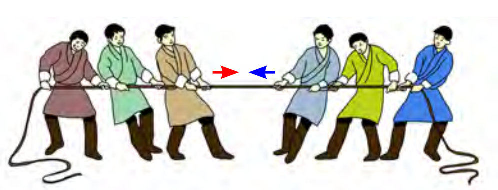
- explain momentum and state its effect on vehicle stopping distances.
- explain that balanced forces do not alter the velocity of a moving object.
- demonstrate that mass is the property of a body which resists change in motion.
- apply equations of motions to simple numerical problems.

## A. Balanced and unbalanced forces

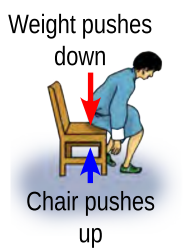
A body may be acted upon by one or more number of external forces. Suppose a number of external forces act on a rigid body at rest from different directions and the body remains at rest. Then the external forces have cancelled each other's effect and there is no resultant force. Similarly, if a rigid body in motion is acted upon by two equal forces acting in opposite direction along the same line of action then the body continues to move with the same velocity. Such forces acting on rigid bodies which do not bring change in its state are called balanced forces. So balanced forces do not alter the state or velocity of a rigid body. They may simply change the shape




Two people pushing a box with equal forces but opposite in direction



A tug of war in which the rope does not move to either side




A person sitting on a chair


A person standing

*Figure 1.10*

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and size of a non-rigid body. Figure 1.10 shows some examples of balanced forces.

On the other hand, when multiple forces act on a rigid body and the resultant force brings change in the state of the body then the forces are called unbalanced forces. Unbalanced forces acting on a body may change the dimension and alter the velocity or direction of a body in motion.

A pair of forces that act on body and has different magnitude form unbalanced force. Unbalanced force causes

- a stationary rigid body to move.
- a moving rigid body to stop.
- a moving rigid body to increase or decrease its velocity.
- a moving rigid body to change its direction.
- change in shape and size of non-rigid body.

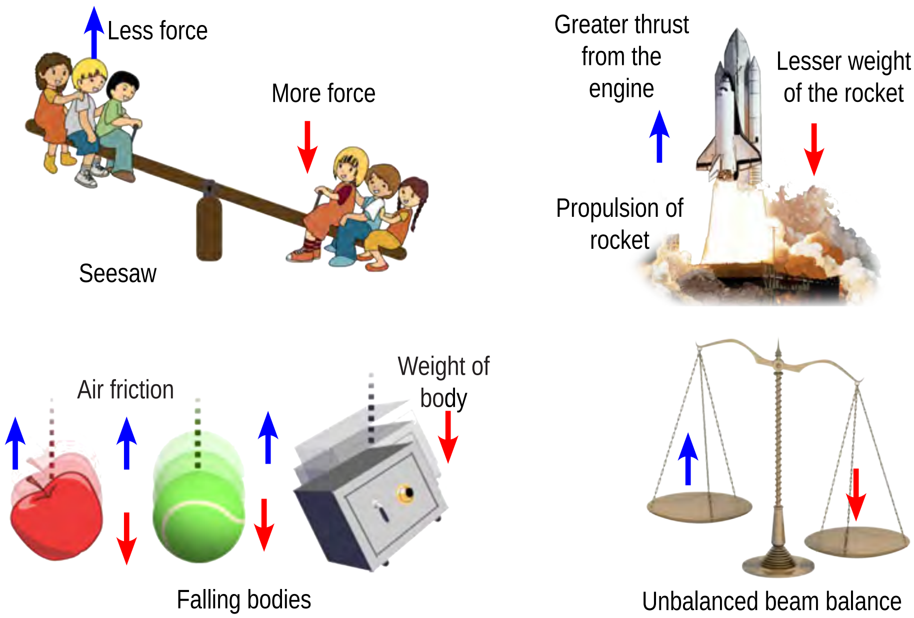


*Figure 1.11*

## B. Momentum of a body

A stationary body under the influence of unbalanced forces starts to move. The moving body accelerates or decelerates depending on the magnitude of the forces. It is a common experience that it is difficult to stop a huge moving body, or a body moving at a great speed. For example, if a truck and a bicycle both moves at a velocity of 10 km/hr, it is relatively easier to stop the bicycle than the truck. On the other hand, if two bicycles of same masses move at different velocities, it will be easier to stop the bicycle that is moving at the lower velocity. In all these cases, we find that, the ability or tendency of a moving body to remain in the state of motion is called momentum of the moving body. Momentum is determined by the mass and the velocity of the moving body. Therefore, the momentum of a moving body is defined as the product of mass and velocity of the moving body. It is represented by 'p'.

*Momentum (p) = mass (m) × velocity (v)*

The units of momentum can be derived by using the above formula. If mass is in kg and velocity is in m/s, the unit of momentum is kg m/s. Momentum is a vector quantity and it is always along the direction of velocity.

**Example 1.3**

A baseball of mass 0.3 kg and a tennis ball of mass 0.5 kg possess equal momentum. What is the velocity of tennis ball if the baseball is moving at 21 $ms^{-1}$?

**Solution:**

$$\text{Momentum of the baseball} = \text{mass} \times \text{velocity}$$

$$= 0.3\ kg \times 21\ ms^{-1}$$

$$= 6.3\ kgms^{-1}$$

*Momentum of two balls is the same.*

$$\text{So, Momentum of tennis ball} = \text{mass } (m) \times \text{velocity } (v)$$

$$= 0.5\ kg \times \text{velocity}$$

$$\text{Momentum of the baseball} = \text{Momentum of the tennis ball}$$

$$\text{i.e, } 6.3\ kg\ ms^{-1} = 0.5\ kg \times \text{velocity}$$

$$\text{velocity} = (6.3\ kg\ ms^{-1})/(0.5\ kg) = 12.6\ m\ s^{-1}$$

## C. Equations of linear motions

Kinematics deals with the study of describing the motion of bodies. It is necessary to study about motions completely with accuracy and consistency. Generally, three equations are used to learn about the motion. In all these equations, specific letters are used to denote various physical quantities namely: 'u' for initial velocity, 'v' for final velocity, 't' for time taken, 'a' for acceleration, and 'S' for distance covered. Each of these equations are discussed in the following paragraphs.

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We know that acceleration is the rate of change of velocity.

$$acceleration = \frac{final\ velocity\,(v) - initial\ velocity\,(u)}{time\ taken}$$

$$a = \frac{v - u}{t}$$

i.e., $v\text{-}u = at,\ v = u + at$

$$\boldsymbol{v = u + at} \text{ ......... } \textbf{\textit{equation 1}}$$

In case of deceleration or retardation, we use '–a' in place of 'a', therefore the above equation changes to

$$v = u - at$$

If the distance 'S' is travelled in time 't' by a moving body of average velocity $(\frac{u+v}{2})$ then,

$$S = (\frac{u+v}{2})\,t \quad (distance = velocity \times time)$$

From ***equation 1***, $v = u + at$

$$S = (\frac{u + (u + at)}{2})\,t$$

So, $S = \frac{2u + at}{2}\,t$

$$S = ut + \frac{1}{2}at^2$$

Therefore, $\boldsymbol{S = ut + \frac{1}{2}at^2}$ ......... ***equation 2***

In case of retardation, ***equation 2*** becomes, $S = ut - \frac{1}{2}at^2$

Now, squaring the ***equation 1***, we get,

$$v^2 = (u + at)^2$$

$$v^2 = u^2 + 2uat + a^2t^2$$

$$v^2 = u^2 + 2a\,(ut + \frac{1}{2}at^2) \text{ ......} \textbf{\textit{equation 3}}$$

From ***equation 2***, we know, $\boldsymbol{S = ut + \frac{1}{2}at^2}$, so substituting in ***equation 3***, we get

$$\boldsymbol{v^2 = u^2 + 2\,aS} \text{ ......... } \textbf{\textit{equation 4}}$$

Incase of retardation, ***equation 4*** changes to, $v^2 = u^2 - 2\,aS$

Earth exerts a uniform acceleration on all freely falling bodies on its surface. In this case, the acceleration on a falling body is equal to the acceleration due to gravity '**g**'. The value of '**g**' at the equator and the poles are different. Its average value is taken as 9.8 m / s$^2$. Therefore, the three equations of linear motion for a falling body on the surface of the Earth are:

$v = u + gt$, for an object falling on the surface of the Earth, and

$v = u - gt$, for an object moving away from the surface of the Earth.

Similarly,

$S = ut + \frac{1}{2}gt^2$, for an object falling on the surface of the Earth, and

$S = ut - \frac{1}{2}gt^2$, for an object moving away from the surface of the Earth.

Finally,

$v^2 = u^2 + 2\,gS$, for an object falling on the surface of the Earth, and

$v^2 = u^2 - 2\,gS$, for an object moving away from the surface of the Earth.

**Tips for solving numerical in Physics**

***Steps you need to follow, while working on numerical in Physics are:***

Step 1: Write down the given values. Remember to include their units and symbols.

Step 2: Using symbols, write down the correct equation(s) or formulae that is necessary to solve the numerical.

Step 3: Substitute the known values. Remember to include both magnitudes and units.

Step 4: Solve for the required values with correct units. Usually you should work out to two decimal places.

### Example 1.4

The brakes applied to a car produce a retardation of 12 ms$^{-2}$. As a result, the car comes to halt in 4 s. Calculate the distance it travels after the brakes are applied, till it stops.

### Solution:

*The known values are:*

$a = -12\ ms^{-2}$ *(minus sign indicates negative acceleration),* $t = 4\ s$ *and* $v = 0\ ms^{-1}$

*We have to calculate* $S = ?$

*We know:* $v = u + at$

$0 = u + (-12\ ms^{-2}) \times 4\ s$

*i.e,* $u = 48\ ms^{-1}$

*We also know:* $S = ut + \frac{1}{2}at^2 = (48\ ms^{-1}) \times (4\ s) + \frac{1}{2}(-12\ ms^{-2}) \times (4\ s)^2$

$S = 192\ m - \frac{1}{2} \times 192\ m = 192\ m - 96\ m = 96\ m$

*The car will come to halt after 96 m after the brakes are applied.*

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# 3. Newton's Laws of Motion

## Learning Objectives

On completion of this topic, you should be able to:

- explain Newton's first law of motion.
- derive the equation of Newton's second law of motion.
- use f = ma, and the equations of linear motion to solve simple numerical problems.
- explain Newton's third law of motion.
- explain the applications of Newton's laws of motion.
- define one newton of force.

## A. Newton's three laws of motion

### *i. Newton's first law of motion*

This law states that, an object at rest or motion continues to be in that state, unless acted upon by an unbalanced force. This means a body at rest like a ball continues to be at that state, unless unbalanced forces make it to move away from that position. Similarly, a body moving with a constant velocity continues to do so, unless some unbalanced forces make it to change that state. The change in velocity is either the increase or decrease of the magnitude of velocity, or the direction, or both.

A body with greater mass has more tendency to be at rest or in motion, than a body with lesser mass. The tendency of a body to remain at rest or in uniform motion is called inertia. Depending upon the state of the body, inertia is of two types: inertia of rest and inertia of motion. The tendency of body to remain at rest is called inertia of rest. The tendency of a body to continue in uniform motion is called inertia of motion. The Newton's first law of motion states that a body continues to remain in the inertia of rest or motion, unless it is forced to change by applying an unbalanced force. So, the first law is also known as law of inertia.

It is a common experience that when a bus suddenly starts, the passengers inside the bus have a tendency to fall backwards. This is due to inertia of rest. Initially the passengers are at rest and their bodies tend to remain at rest even when the bus starts moving.

Similarly, when a moving bus suddenly stops, the passengers have a tendency to fall forward due to inertia of motion. Since the bodies of the passengers were already in motion along with the bus, they tend to remain in the state of motion even when the bus comes to rest.

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## ii. Newton's second law of motion

**Activity 1.4** — **Relationship between force applied on a body (f), mass of the body (m) and acceleration(a) produced.**

Materials required: 10 numbers of 100 gf weights, trolley, table top, string and stop watch/digital timer.

Investigation 1

### Procedure

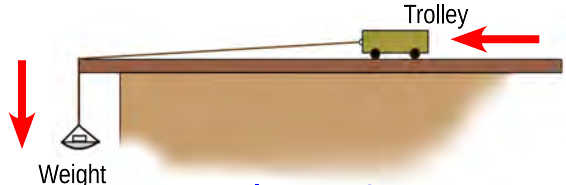


*Figure 1.12*

**Step 1** Set up the apparatus as shown in the Figure 1.12.

**Step 2** Measure the length of the table top and record it as 'd' = ……........m.

**Step 3** Let the trolley (mass) be pulled by placing 100 gf in the pan. Record the time taken by the trolley to reach the end of the table top. Carry out this step thrice and record your reading in Table 1.2.

Table 1.2

| Sl. No. | Time Taken (seconds) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| Total Time | |
| Average Time | |
| Average Velocity | |

**Step 4** Now, calculate average velocity of the trolley and record it in the Table 1.2.

**Step 5** Next, repeat Step 3 and Step 4, by placing 200 gf, 300 gf, 400 gf and 500 gf in the pan.

**Step 6** Plot a graph of the pulling force (weight in gf) against the velocity of the trolley.

Answer the following question.

1. What is the relationship between the velocity of the moving trolley and the force acting on it?

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Investigation 2

## Procedure

**Step 1** ☞ Set up the apparatus as shown in the Figure 1.12.

**Step 2** ☞ Put a mass of 500 g in the trolley.

**Step 3** ☞ Now, increase the weights in the pan until the trolley just starts to move.

**Step 4** ☞ Record the time taken by the trolley to travel the length of the table top. Carry out this step three times and record your observation in Table 1.3. Calculate the average time taken and record in Table 1.3.

Table 1.3

| Sl. No. | Time Taken (seconds) |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| Total Time | |
| Average Time | |
| Average Velocity | |

**Step 5** ☞ Now, calculate average velocity of the trolley and record it in the Table 1.3.

**Step 6** ☞ Next, repeat Step 2 to Step 5, with mass of 400 g, 300 g, 200 g and 100 g in the trolley.

**Step 7** ☞ Plot a graph of masses against the average velocities.

Answer the following question.

1. What is the relationship between average velocity and mass of the moving body?

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***Complete the following sentences:***

From investigation 1, we conclude that, the trolley moves with ………. (more/less) acceleration, when the pulling force due to weights in the pan increases.

From investigation 2, it is evident that, the acceleration of a moving body …………….. (increases/decreases) with its mass, when the net force acting on it, is same.

From activity 1.4, we conclude the following:

The acceleration produced on the moving body 'a' is directly proportional to net force 'f' acting on it.

Mathematically, we write it as:

$$a \propto f \quad \text{----- } \textit{equation 1}$$

The acceleration produced on the moving body 'a' is indirectly proportional to its mass, 'm'.

Mathematically, we write it as:

$$a \propto \frac{1}{m} \quad \text{----- } \textit{equation 2}$$

Now, combining equations (i) and (ii), we get,

$$a \propto \frac{f}{m}$$

$$\text{i.e, } f \propto ma$$

$$\text{i.e, } f = k.ma,$$ where 'k' is the constant of proportionality.

The value of the proportionality constant is equal to one, when mass of the moving body is 1 kg, acceleration produced on the body is 1 $ms^{-2}$ and the force is 1 N.

Therefore, the equation for Newton's second law is

$$f = ma \quad \text{--- } \textit{equation 3}$$

The magnitude of a force that produces an acceleration of 1 $ms^{-2}$ on a body of mass 1 kg is called 1 N force.

Equation 3 can be rewritten as,

$$f = m\left(\frac{v - u}{t}\right)$$

$$\text{or } f = \frac{mv - mu}{t} \quad \textit{since,} \quad a = \frac{v - u}{t}$$

We know that, the product of mass and velocity of a moving body is momentum of the body.

So, $$f = \frac{p_f - p_i}{t},$$

where $p_f$ and $p_i$ are the final momentum and initial momentum respectively.

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Therefore, *force = rate of change of momentum.*

Newton's second law of motion is defined as, force acting on a moving body is directly proportional to the rate of change of momentum of the body in the direction of the applied force.

**Example 1.5**

A sports car accelerates from 0 to 27 $ms^{-1}$ in 6.3 s. The car exerts a force of 4106 N. What is the mass of the car?

**Solution:**

*We know that* $u=0\ ms^{-1}$ *and* $v=27\ ms^{-1}$

*Change in velocity* $= v - u = 27\ ms^{-1} - 0 = 27\ ms^{-1}$

*Time taken for change in velocity* $= 6.3\ s$

*Force* $= 4106\ N$

*We know, acceleration* $a = \frac{v-u}{t} = \frac{27-0}{6.3} = 4.29\ ms^{-2}$

*From Newton's second law of motion,* $\boldsymbol{f = ma}$

$$m = \frac{f}{a} = \frac{4106}{4.29} = 957.11\ kg$$

## iii. Newton's third law of motion

We know that, forces exist in pairs. When we sit on a chair, there are two forces operating, weight of our body acts downward and a force that is equal in magnitude act upward to balance it. One of the forces in operation like the weight of the body is called action, and the other force like the force exerted upward by the chair on the body, that is equal in size but acts in the opposite direction is called reaction. Figure 1.13 shows some more examples of action and reaction forces in operation in our day to day life.

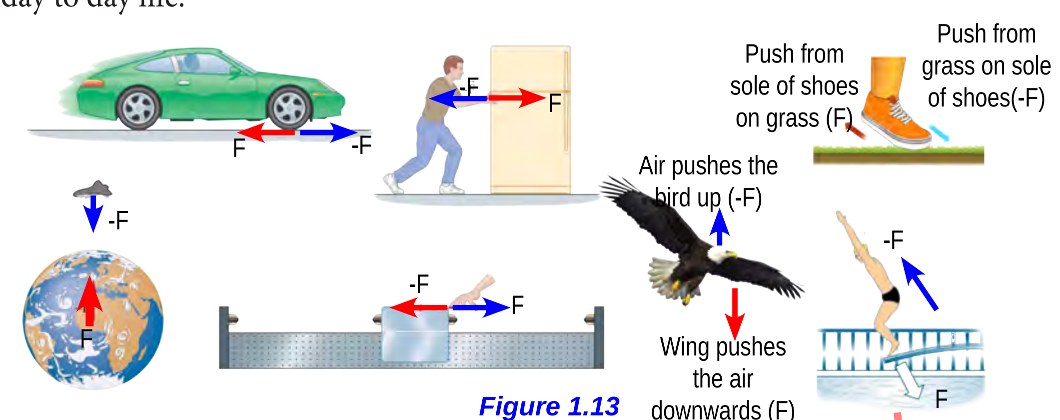


*Figure 1.13*

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Newton's third law relates the action and reaction forces, and states that, for every action there is an equal and opposite reaction.

## Activity 1.5 Exploring Newton's third law

Materials required: Balloon.

### Procedure

**Step 1** ☞ Inflate a balloon. Hold the mouth of the balloon tightly, so that air does not escape.

**Step 2** ☞ Place it on a table top. Now release the mouth of the balloon to release air. Observe carefully.

Now answer the following questions.

1. What happens to the balloon when you release the mouth?
2. Identify action and reaction in the above event.
3. The rushing air pushing back the balloon is the reaction. Explain the observation.
4. In the past, people thought that rocket cannot move and accelerate in the space because there was nothing that rocket could push off in the space. Something is necessary for propulsion. Which of the following statements is true? Give a reason to support your answer
   a. There is no gravity in space.
   b. There is no air resistance in space.
   c. As there is no air in space, there is nothing to push off.
   d. This is not true, rockets moves and accelerates in space.

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## Summary

- Speed is the average distance travelled by a body in a given time period. Speed is a scalar quantity.
- Velocity is the rate of change of displacement in a given time period. Velocity is a vector quantity.
- The circular movement of a body is called curvilinear motion. The movement of a body in a straight line is called rectilinear motion.
- The slope of a displacement-time graph represents the velocity of a moving body.
- The slope of velocity-time graph indicates the acceleration of a moving body. If the slope is negative it indicates negative acceleration or deceleration, or retardation.
- The area under the graph of a velocity-time graph indicates the displacement of the moving body.
- A straight line graph inclined at an angle of $45^0$ to the Y-axis shows that the body is increasing its velocity uniformly.
- If the slope of the straight line graph parallel to X-axis is zero, it means that there is no change in the velocity of the moving body. Hence, the body does not undergo any acceleration.
- If the velocity-time graph is a curve, it indicates that the velocity changes inconsistently with time, that is, it is undergoing variable acceleration.
- A straight line distance-time graph in which it is parallel to the Y-axis is not practical. Such a graph means indefinite distance is covered in no time.
- Acceleration is the rate of change of velocity. It is generally measured in $ms^{-2}$.
- Forces that do not alter the state or velocity of a rigid body are called balanced forces.
- Forces that bring about change in the state or velocity of a rigid body are called unbalanced forces.
- The momentum of a moving body is defined as the product of mass and velocity of the body.
- The three equations of linear motion are: $v = u + at$, $S = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2aS$ .
- The Newton's first law of motion states that a body continues to remain in the inertia of rest or motion, unless it is forced to change by applying an unbalanced force. The first law is also known as law of inertia.
- One newton is the force that acts on a body of mass 1 kg and produces an acceleration of 1 $ms^{-2}$.
- Newton's second law of motion states that, force acting on a moving body is directly proportional to the rate of change of momentum of the body.
- Newton's third law of motion states that, for every action there is an equal and opposite reaction.

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## Exercises

### I. *Fill in the blanks.*

1. Action and reaction forces are always the same in ……………… but are in opposite ……………….
2. When a pair of unbalanced forces act on a stationary rigid body, it is more likely that the body will move in the direction of the ……………force.
3. Momentum of body depends on mass and ……………………..
4. Speed of a body in a particular direction is known as……………………..
5. Scalar quantities have ……………..only.

### II. *Match the following.*

| Column A | Column B |
|---|---|
| 1. Acceleration | A. A tendency of a body to keep moving. |
| 2. Kinematics | B. Fastness and direction of a body. |
| 3. Inertia | C. An opposite force. |
| 4. Velocity | D. A study of moving bodies. |
| 5. Reaction | E. A state of balance of forces on a body and the body remains either at rest or in uniform motion. |
| | F. An increase in a body's speed. |
| | G. An increase in a body's velocity. |

### III. *Multiple Choice Questions*

1. The graph in Figure 1.14, shows the journey of Yangden from her house to the monastery. What is one possible interpretation of the section of the graph from point B to point C?

   A Yangden arrived at the monastery and stayed there throughout the day.

   B Yangden waited for a while before resuming her journey.

   C Yangden returned home to get her butter lamps.

   D Yangden reached the top of a hill and began walking on level ground.

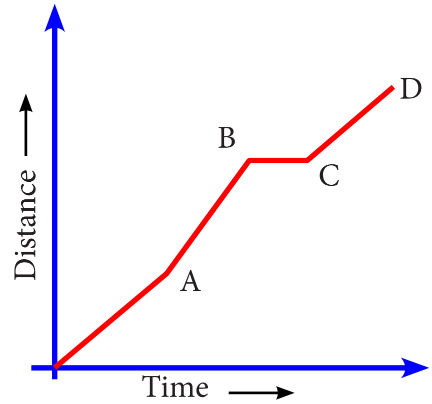


*Figure 1.14*

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2. The initial velocity of a body moving from rest is
   A  0 $ms^{-1}$.
   B  1 $ms^{-1}$.
   C  2 $ms^{-1}$.
   D  3 $ms^{-1}$.
3. According to Newton's First Law of Motion, an object in motion will
   A  slow down when moving down a hill.
   B  stay in motion unless acted upon by an outside force.
   C  always move sideways when acted upon by an outside force.
   D  stay in motion when it is acted upon by an outside force.
4. A body is moving with negative acceleration. Which one of the following statements is true in the context of this body?
   A  The body is just starting to move.
   B  The body is falling freely on the ground.
   C  The body is coming to a halt.
   D  The body is moving with constant velocity.
5. The following are statements regarding distance-time graphs.
   *I  The steeper the graphs, the faster the motions.*
   *II  Horizontal lines means the object is not changing its position(not moving).*
   *III  Horizontal lines means the object is moving on a plane surface.*
   *IV  Downward sloping line means the object is returning to the initial position.*

   Which of these pair of statements is correct regarding these graphs?
   A  I and IV.
   B  II and III.
   C  I and III.
   D  III and IV.
6. Which of following statements best describes the motion of a body shown by the graph in Figure 1.15 ?
   A  The body is traveling at a constant speed.
   B  The body is slowing down.
   C  The body is accelerating.
   D  The body is stopped.

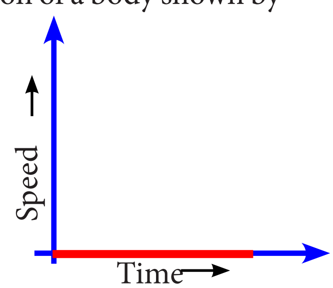


*Figure 1.15*

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7. Pelden pushes a box of mass 30 kg with a force of 60 N. What is the acceleration of the box?
   - A $1\ ms^{-2}$
   - B $2\ ms^{-2}$
   - C $0.5\ ms^{-2}$
   - D $1800\ ms^{-2}$
8. Which of the following phenomenon is best explained by Newton's third law of motion?
   - A A coin on a piece of paper remains at the same position, when the piece of paper is removed swiftly.
   - B A huge rock rolls over a cliff when pushed over.
   - C A toy steam boat moves in water by pushing steam backward into the water.
   - D A person getting off a moving bus runs for some time, before stopping.
9. Which one of the following unit represents a force?
   - A J
   - B kgms
   - C N
   - D W
10. A 5 kg object is accelerating uniformly with $0.5\ m\ s^{-2}$ from rest for 10 s. Find the change in momentum of the object.
    - A $25\ kg\ ms^{-1}$
    - B $32\ kg\ ms^{-1}$
    - C $30\ kg\ ms^{-1}$
    - D $18\ kg\ ms^{-1}$

***IV. State 'True' or 'False'. Rewrite the false statements correctly.***

1. Inertia is a force which keeps stationary objects at rest and moving objects in motion.
2. Unbalanced forces cause stationary objects to move.
3. It is the natural tendency of all bodies to eventually come to a rest position.
4. If a car is accelerating to the left, resultant force on the car must be towards left.
5. A free-falling object on the Earth experiences balanced forces.

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## V. *Answer the following questions.*

1. A bicycle possesses 1000 units of momentum. What would be the bicycle's momentum if,
   a its velocity is doubled.
   b its mass is tripled.
2. Give an example of a body with uniform acceleration.
3. A car is travelling at a speed of 70 km/hr for 2 hours.
   a Draw a graph to represent the journey.
   b Using the graph, calculate the total distance travelled by the car.
4. How long would it take for a resultant upward force of 100 N to increase the speed of 50 kg object from 100 $ms^{-1}$ to 150 $ms^{-1}$?
5. A worm travels up a tree, from the ground, for duration of 30 s. Initially it moves fast and gradually slows down. It stops for 10 seconds, then proceeds slowly, speeding up again as it climbs up. Draw a distance-time graph to illustrate the worm's journey?
6. Write a story that best explains the motion shown by the graph given in Figure 1.16.

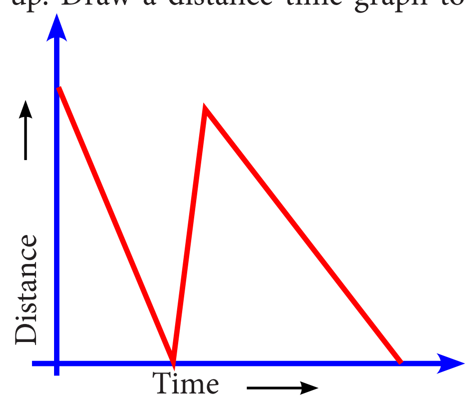

*Figure 1.16*

7. Classify the following situations as examples of Newton's first law, second law and third law. Justify your classification.
   a A portrait hung on the wall does not move.
   b Pushing a child on a swing is much easier than an adult on it.
   c A person pulls a table cloth swiftly and plates and mugs remains on the table.
   d A ball moves fast if kicked hard.
   e A bird flaps its wings to fly higher.
8. A bullet is fired at 660 $ms^{-1}$ and strikes a target 200 m away. How long has it taken to hit the target?
9. Calculate the mass of a bus if it produces a force of 14,000 N while accelerating at a rate of 5 $ms^{-2}$ ?
10. You toss a ball at 30 $ms^{-1}$ straight upward. How much time will the ball take to reach the top of its path?

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11. How much time does a bike with an acceleration of 2 $ms^{-2}$ take to increase its velocity from 10 $ms^{-1}$ to 30 $ms^{-1}$?
12. A van accelerates at a constant rate from 18 km/hr to 54 km/hr in 5 s. What is the acceleration? If the car now takes 4 s to stop, what is the retardation?
13. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 $ms^{-2}$, with what velocity will it strike the ground? After what time interval will it strike the ground?
14. A motorist traveling at 70 $ms^{-1}$ passes a policeman who immediately accelerates to catch the motorist. If the policeman catches the motorist in 16 s, what is the policeman's acceleration?
15. The first 10 m of a 100 m dash are covered in 2 s by a sprinter who starts from rest and accelerates constantly. The remaining 90 m is run with the same velocity the sprinter had after 2 s. In this context, answer the following questions.
    - a Calculate the sprinter's constant acceleration during the first 2 s.
    - b What is the sprinter's velocity after 2 s?
    - c Calculate the total time required to run the full 100 m.
    - d Draw the displacement-time graph for the sprinter.
16. 1. Classify the following situations as examples of 'balanced' and 'unbalanced' forces.
    - a Two forces of 20 N acting towards left.
    - b An accelerating plane.
    - c An object at rest.
17. A bike starts from rest and reaches a speed of 5 ms-1 after travelling with uniform acceleration in a straight line for 2 s. Calculate the acceleration of the body.
18. A basketball of mass 250 g travelling at 2 ms-1 under goes head-on collision with another identical ball at rest. The first ball stops and the second one move off. What is the velocity of the second ball?
19. A van accelerates from 4 ms-1 to 20 ms-1 in 8 s. How far does it travel in this time?
20. What force is needed to give an acceleration of 2 ms-2 to a body of mass 3 kg?
21. Arrange the following bodies in their ascending order of inertia:

    A tennis ball, a small car, a truck, a feather, a bull dozer

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2

# Pressure and its Applications

## 1. Pressure in Fluids

**Learning Objectives**

On completion of this topic, you should be able to:

- define pressure.
- state laws of liquid pressure.
- derive the expression, p= hdg, at a point inside a liquid.
- describe atmospheric pressure.
- explain the working of different types of barometer.

A body exerts force equal to its weight on the surface on which it is lying. The total force that acts normally on the surface in contact is called *thrust*. If the thrust applied is same, the effect of thrust depends on the area of surface in contact. The thrust acting on a unit area of the surface in contact is called *pressure*.

$$Pressure = \frac{Thrust\,(F)}{Area\,(A)}$$

Pressure is a scalar quantity and usually measured in $Nm^{-2}$. Other units are pascal (Pa), bar and millibar.

$1\ Nm^{-2} = 1\ Pa$, $1\ bar = 10^5\ Nm^{-2}$ and $1\ millibar = 10^2\ Nm^{-2}$.

Substances that flow are called fluids. Fluids like liquids and gases exert pressure on the surface of the container.

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## A. Pressure inside a liquid

**Activity 2.1** **Investigating pressure inside a liquid**

Materials required:

A new U- tube with some ink in it, rubber tubing, marker pen, thin rubber membrane, funnel, a bucket of water, strings.

### Procedure

**Step 1** Construct the manometer, as shown in Figure 2.1.

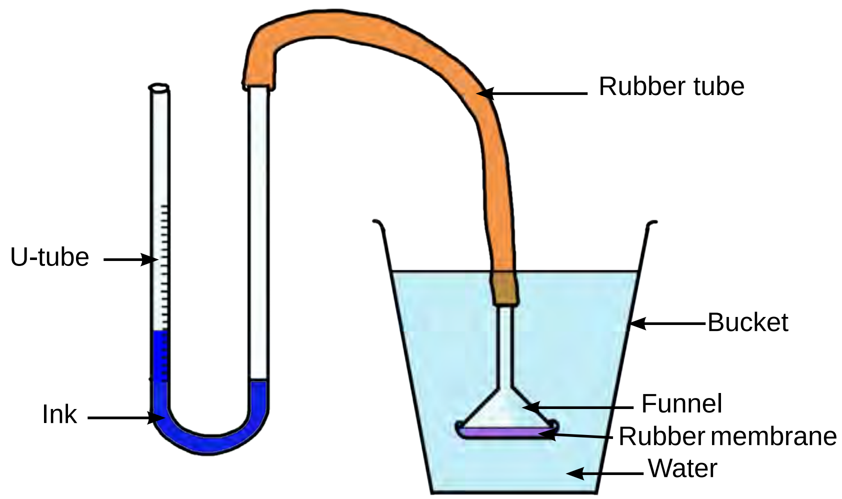


Figure 2.1 Manometer

**Step 2** Put a small amount of ink in the U-shaped tube.

**Step 3** Gradually, dip the funnel to a depth of about 3 cm inside the water in the bucket. Observe the change in levels of the ink in the two arms of the U-tube, and mark the levels in both the arms of the U tube. Move the funnel horizontally at constant depth of 3 cm inside the water. Observe the level of the ink in the U tube.

**Step 4** Keeping the funnel at the same depth inside the water, turn the funnel in different directions. Observe the change in levels of the ink in the two arms of the U-tube, and mark the levels in both the arms of the U tube.

**Step 5** Now lower the funnel to a depth of 7 cm, maintaining the same direction of the funnel mouth. Observe the level of the ink in the U-tube, and mark the levels on the U tube.

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**Step 6** ☞ Further lower the funnel to a depth of 10 cm without changing the direction of the funnel mouth. Observe the level of the ink in the U-tube, and mark the levels on the U tube.

**Step 7** ☞ Repeat step 6 with concentrated salt solution . Then compare the levels of the ink in the U tube in steps 6 and 7.

**Copy and complete the following.**

The ink level in the U tube remains same when the funnel is moved horizontally at a constant .......... inside the liquid. Step 4 shows that liquid pressure at a point is same in all .................. When the funnel is pushed deeper inside a liquid, the ink level in the left arm of U tube rises. This indicates that the pressure inside the liquid increases with ............., and vice versa. The ink level is relatively.............. in water than in salt solution when the funnel is kept at the same depth . Therefore the liquid pressure is ..................... in liquids of different densities. The instrument used to detect the fluid pressure is called ..................

In reference to conclusion from the Activity 2.1, deduce the four laws of liquid pressure.

*First Law: The pressure is same at all points in a .........................*

*Second Law:…………..*

*Third Law: ………………………..*

*Fourth Law: ........................*

In addition, we have one more law of liquid pressure, which is stated as given below.

*Fifth Law:* Liquid finds its own level. Irrespective of the shape of the vessel, liquid takes its own level. For instance, when water is poured into a specially designed vessel called communicating tubes, the level of the water in all tubes is same as shown in Figure 2.2.

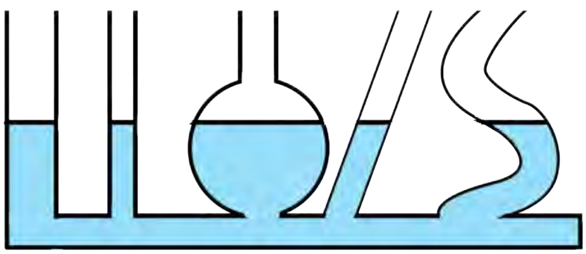

Figure 2.2 Liquid level

## B. Pressure at a point inside a liquid

Figure 2.3 shows a beaker containing a certain liquid. Consider the liquid column indicated by letters WXYZ inside the beaker. Let the area of the liquid column be 'A', density be 'd' and the depth below the surface be 'h'.

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Then, volume of the liquid column WXYZ = Ah (since, $A = l \times b$)

And, mass of the liquid column WXYZ = volume × density

i.e, ***mass = Ahd***

The thrust due to the liquid column WXYZ is equal to the thrust due to its weight.

i.e. thrust = mg,

***thrust = Ahdg***

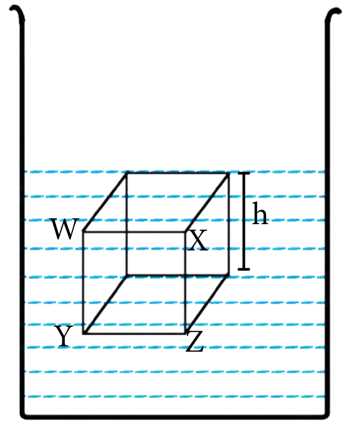

Figure 2.3

We know,

$$Pressure = \frac{Thrust\,(F)}{Area\,(A)}$$

Pressure at a point in the $liquid = \frac{Ahdg}{A}$,

i.e. **Pressure = hdg**

Therefore, pressure at a point inside a liquid = hdg

where, h = depth of the point inside a liquid.

d = density of the liquid.

g = acceleration due to gravity.

The three factors that affect the pressure at a point inside a liquid are:

1. *depth inside the liquid,*
2. *density of the liquid, and*
3. *acceleration due to gravity at that place.*

**Example 2.1**

Calculate the height of water column which will exert on its base the same pressure as 70 cm column of mercury. Density of mercury is 13.6 $gcm^{-3}$.

**Solution:**

*The pressure exerted by the column of mercury = The pressure exerted by the column of water*

i.e., $h_m d_m g = h_w d_w g$

i.e., $70\ cm \times 13.6\ g\ cm^{-3} = h_w \times 1\ g\ cm^{-3}$

i.e, $h_w = 952\ cm$ or $9.52\ m$

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**Example 2.2**

The pressure on the ground floor is 5 x $10^4$ Pa and at the first floor, it is 2 x $10^4$ Pa. What is the height of the first floor? Given the density of water is $10^3$ $kgm^{-3}$ and g is 10 $ms^{-2}$.

**Solution:**

*Pressure on the ground floor = Pressure on the first floor + hdg*

i.e., $5 \times 10^4 = 2 \times 10^4 + (h \times 10^3 \times 10)$

i.e., $h \times 10^4 = 3 \times 10^4$

or $h = 3$ m

*Therefore, the height of the first floor is 3 m.*

## C. Atmospheric pressure

Our Earth is covered with a thick layer of air. The column of air exerts pressure due to its weight on the surface of the Earth. This pressure is known as *atmospheric pressure*. Atmospheric pressure varies from place to place, due to changing density of the air.

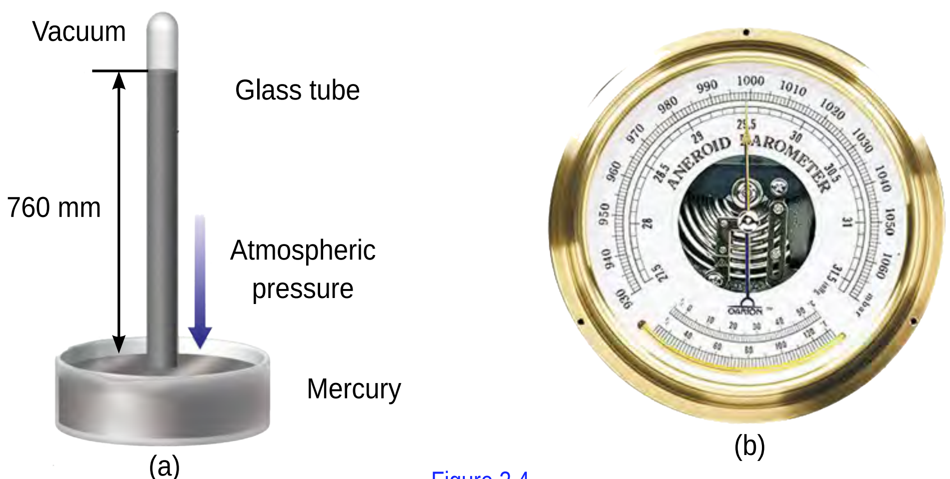


Figure 2.4

Atmospheric pressure is measured by a mercury barometer and, therefore, atmospheric pressure is also commonly referred to as barometric pressure. Figure 2.4 (a) shows a simple barometer. It consists of a glass tube with one end open. The tube is filled with mercury. This glass tube is placed upside down in a container, called the reservoir, which contains mercury. The mercury level in the glass tube falls, creating a vacuum at the top.

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The height of the mercury column in the tube indicates the atmospheric pressure at a place. For instance, the atmospheric pressure at the sea level is 760 mm, or 76 cm of mercury. The first barometer of this type was devised by Evangelista Torricelli in 1643.

More commonly used barometer is an aneroid barometer, owing to its portability since no liquid is used in this instrument. Aneroid barometer was invented in 1844 by a French scientist, Lucien Vidi. Instead of liquid like mercury, this instrument has a sealed, air-tight metal box inside. As the atmospheric pressure rises or falls, the box either squashes inward a little bit, or stretches outward. A spring attached to the box either moves in or out in response to the changes in air pressure. As the spring expands or contracts, the pointer on the dial moves. With the help of the scale on the dial, the atmospheric pressure at that instant is recorded. An aneroid barometer is shown in Figure 2.4 (b). This instrument is also called *altimeter*.

## D. Atmospheric pressure and weather forecasting

One of the common ways to forecast changes in weather is by observing the changes in atmospheric pressure. The ways the atmospheric pressure changes foretells the weather conditions for the region like rainfall, storm, heat waves, cyclones, fair weather, etc. For instance, a gradual rise in atmospheric pressure over a few days, usually indicates good weather. On the other hand, a sudden fall in atmospheric pressure in a few hours indicates storm accompanied by heavy rain.

The following weather predictions can be made by observing the change in the barometer.

- If the barometric pressure decreases gradually, it indicates rainfall.
- If there is a sudden fall in the barometric pressure, then there is possibility of storm and cyclone.
- A gradual increase in the barometric pressure forecasts fair weather.
- Sudden increase in the barometric pressure indicates fair weather with possibility of rainfall.

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## Questions

1. Why does pressure on a diver increase with depth?
2. The pressure in a water pipe in the ground floor of a building is $4 \times 10^5$ Pa and three floors up is $2 \times 10^5$ Pa. What is the difference in height between the ground floor and the third floor? Density of water = $1 \times 10^3$ kgm$^{-3}$.
3. Calculate the pressure at a point that is 100 m below the surface of sea water of density 1150 kgm$^{-3}$.
4. Which of the following statements is TRUE about Figure 2.5?
   a. Pressure at point A is greater than pressure at point B.
   b. Pressure at point B is greater than pressure at point A.
   c. Pressure at point A and point B are same.
   d. Pressure at point B and point A are different.

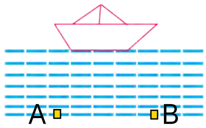

Figure 2.5

5. Why is aneroid barometer preferred over a mercury barometer?
6. Explain any two factors that affect the pressure at a point inside a liquid.

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# 2. Buoyant Force

## Learning Objectives

On completion of this topic, you should be able to:

- explain upthrust.
- state factors affecting the upthrust on a body.
- derive the expression for calculating upthrust.
- state Archimedes' Principle.
- carry out an experiment to prove Archimedes' Principle.
- define density and relative density (R.D.) of a substance.
- determine density of irregular solids and liquids, using Archimedes' principle.

## A. Upthrust

Did you ever wonder, why a ship floats in water, or a balloon rises in air? It is a common experience that an inflated ball floats on the surface of water bodies. Similarly, a balloon filled with light gas, like helium rises in air and it is easy to lift a bucket of water while inside the water. A body immersed in fluid experiences a force acting upward on it. This upward force is called upthrust or buoyant force. Media like liquids and gases have property of exerting upthrust on anybody when immersed in them. This property of different media to exert upthrust on the immersed bodies is known as buoyancy.

Figure 2.6 shows a body floating on a liquid. Two types of forces operate on such a body: one is the downward force due to the weight of the body and the other is the upthrust acting on the body due to the liquid.

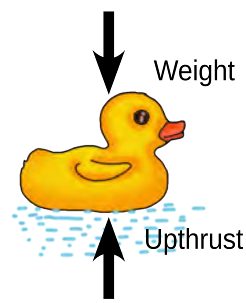

Figure 2.6

Therefore, the resultant force that acts on the body immersed in a liquid is the difference between the two forces that operate on the body, namely the upthrust due to the liquid, and the weight of the body.

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### i. Calculating upthrust

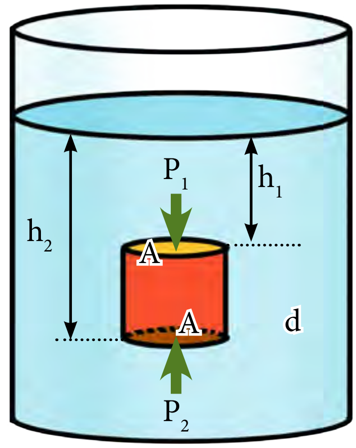

Figure 2.7

Figure 2.7 shows a cylindrical object placed inside a liquid of density 'd'. The cylindrical object has two faces with area of 'A' each.

The lateral pressures cancel each other's effect, while the pressure acting on the upper surface and lower surface are different.

We know, $Pressure = \frac{Thrust\,(F)}{Area\,(A)}$

So, pressure on upper surface, say,

$$P_1 = \frac{Thrust\ on\ upper\ surface}{Area\ of\ the\ upper\ surface}$$

$$\text{i.e., } P_1 = \frac{Weight\ of\ the\ liquid\ column\ above\ the\ upper\ surface}{Area\ of\ the\ upper\ surface}$$

$$P_1 = \frac{mass\ of\ the\ liquid\,(m) \times acceleration\ due\ to\ gravity\,(g)}{Area\ of\ the\ upper\ surface}$$

$$P_1 = \frac{mg}{A} \text{ ...... } \textbf{\textit{equation (a)}}$$

We know, ***mass = density*** $\times$ ***volume***

Therefore, substituting 'mass' in equation (a), we get,

$$P_1 = \frac{density\,(d) \times volume\,(V) \times acceleration\ due\ to\ gravity\,(g)}{Area\,(A)}$$

$$P_1 = \frac{dVg}{A} \text{ ...... } \textbf{\textit{equation (b)}}$$

We also know, $Volume = length\,(l) \times breadth\,(b) \times height\,(h)$

or, volume = A(Area) $\times$ h (height)

Substituting 'volume' in ***equation (b)***,

$$P_1 = \frac{d \times A \times h \times g}{A}$$

$$P_1 = d \times h \times g$$

From the Figure 2.7, the height of the liquid column at the upper surface is $h_1$.

So, $P_1 = dh_1g$

Therefore, downward thrust on the upper surface, say $F_1 = P_1 \times A$

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i.e., $F_1 = dh_1gA$

From the Figure 2.7, the height of the liquid column at the lower surface is $h_2$.

So the thrust acting upward from the lower surface of the cylindrical object,

$$P_2 = dh_2g$$

Therefore, the upward thrust on the lower surface, say $F_2 = P_2 \times A$

i.e., $F_2 = dh_2gA$

***Resultant upward force (upthrust) = Upward thrust on lower surface ($F_2$)***

***– Downward thrust on upper surface ($F_1$)***

$$= h_2dgA - h_1dgA = dgA(h_2 - h_1)$$

Since the volume of the body, $V = A(h_2 - h_1)$

***Upthrust on the object = Vdg --- equation (c)***

where, V = volume of the object immersed inside the liquid

d = density of the liquid

g = acceleration due to gravity

The volume of the immersed object is same as the volume of the liquid displaced by the body. Therefore, the product of volume of the displaced liquid and its density is the mass of the displaced liquid. Mathematically, it is represented as

***Mass of the displaced liquid (m) = volume of the displaced liquid (V) × density of the liquid (d)***

i.e., m = Vd

Then, ***upthrust = mass of the displaced liquid (m) × acceleration due to gravity (g)***

Therefore,

***Upthrust = weight of the liquid displaced by the body.***

Since upthrust is a force, it is measured in newton (N) and dyne. Gravitational units are kilogram-force (kgf) and gram-force (gf).

**1 kgf = 9.8 N**

From equation (c), the three factors that affect the upthrust acting on the body are:

(i) ***The volume of the body submerged in liquid*** – More the volume of body submerged in a liquid, greater is the upthrust acting on the body and vice versa.

(ii) ***Density of liquid in which the body is submerged*** – The upthrust acting on a

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body increases with increase in the density of the liquid in which it is submerged.

(iii) ***Acceleration due to gravity*** – The upthrust acting on the body is directly proportional to the acceleration due to gravity.

When the body is immersed in a liquid, the body appears to lose its weight due to upthrust. This weight of the body inside the liquid is called apparent weight. The actual weight of the body is called true weight. True weight is always greater than the apparent weight.

Therefore,

*Upthrust (Weight of liquid displaced) = True weight – Apparent weight*

## B. Archimedes' Principle

Archimedes' Principle states that when a body is immersed partially or wholly in a fluid (liquid or gases), it experiences an upthrust, which is equal to the weight of the fluid displaced.

In Figure 2.8, when the stone is immersed in water, the weight of the stone decreases and the water displaced by the stone pours out into the beaker. The decrease in weight of the stone is equal to the upthrust exerted by the water, or the weight of the displaced water.

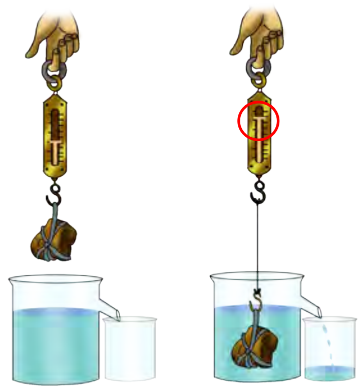

Figure 2.8

### Activity 2.2 Verifying Archimedes' Principle

Materials required:

Displacement can, water, a 250 mL beaker, a small stone, thread, a spring balance and digital weighing machine.

#### Procedure

**Step 1** ☞ Place a displacement can on a levelled surface. Plug in the spout with the help of your hand and fill it up with water till its brim. Then let the water pour out of the spout until the water level reaches the spout height.

**Step 2** ☞ Hang the stone from the hook of the spring balance with the help of a thread. Record its weight in air in Table 2.1.

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**Step 3** ☞ What will happen to the reading on the spring balance, if you place the stone hanging on it, into the water in the displacement can? Record your prediction in Table 2.1.

**Step 4** ☞ Measure the mass of a 250 mL beaker on a digital weighing machine, then place it below the spout of the displacement can.

**Step 5** ☞ Immerse the stone carefully inside water in the displacement can. Observe and record the weight of the stone in water.

**Step 6** ☞ Measure the total mass of the beaker and the displaced water. Calculate the mass of the displaced water and record all the data in Table 2.1.

**Step 7** ☞ Calculate the weight of the displaced water.

Table 2.1

| Weight of the stone in air ($W_a$) | Weight of the stone in water ($W_s$) | Mass of the empty beaker ($m_b$) | Mass of the empty beaker and displaced water ($m_{bw}$) | Mass of the displaced water only ($m_w$)= ($m_{bw}$)-($m_b$) | Weight of the displaced water ($W_w$) = mass of the displaced water ($m_w$) X acceleration due to gravity(g). |
|---|---|---|---|---|---|
| | | | | | |
| Your prediction in Step 3<br><br>........................................................................................... | | | | | |

Now answer the following questions.

1. Was your prediction in Step 3 correct? Explain.
2. Why is the weight of the stone different in air and in water?
3. Calculate upthrust using the relation, upthrust = True weight - Apparent weight.
4. How is the upthrust related to the weight of the displaced water?
5. How is volume of body related to volume of water displaced by the body?

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**Example 2.3**

1. A body weighs 450 gf in air and 310 gf when completely immersed in water. Find
   i. the loss in weight of the body.
   ii. the upthrust on the body.
   iii. the volume of the body. State the assumption made in calculating the volume.

(Given: density of water is 1 $gcm^{-3}$)

**Solution:**

i. *Loss in weight = weight of the body in air - weight of the body in water*

$$= 450 - 310 = 140\ gf.$$

ii. *Upthrust = loss in weight = 140 gf*

iii. *Weight of the displaced water = upthrust = 140 gf*

*mass of displaced water = 140 g*

$$\text{Volume of displaced water } V = \frac{m}{d} = \frac{140\ g}{1\ g/cm^3} = 140\ cm^3$$

*Volume of the body = volume of the displaced water =* $140\ cm^3$

**Example 2.4**

A body weighs 0.8 kg in air, and has a density of 8000 $kgm^{-3}$. It is completely immersed in a liquid of density 5000 $kgm^{-3}$. What is the apparent weight of the body in the liquid?

**Solution:**

*Given:*

*Mass of the body in air = 0.8 kg*

*Density of the body =* $8000\ kgm^{-3}$

$$Density = \frac{Mass}{Volume}$$

$$\text{i.e., Volume of the body} = \frac{Mass}{Density} = \frac{0.8\ kg}{8000\ kgm^{-3}} = 10^{-4}\ m^3$$

$$\text{Upthrust} = \text{Weight of the displaced liquid} = 5000\ kgm^{-3}\ \ 10^{-4}\ m^3 = 0.5\ kgf$$

*Apparent weight = Weight of the body in air – Upthrust*

$$= 0.8\ kgf - 0.5\ kgf = 0.3\ kgf$$

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## C. Density and Archimedes' Principle

Density of a substance is defined as the ratio of the mass to the volume of a substance.

$$\text{i.e, } Density = \frac{Mass}{Volume}$$

It is measured in $kgm^{-3}$ or $gcm^{-3}$.

The density of water is 1 $gcm^{-3}$ or 1000 $kgm^{-3}$ at 4°C. The density of water is maximum at 4°C. As the temperature decreases below 4°C or increases above 4°C, the density of water decreases.

### *i. Relative density (R.D.) of a solid*

Relative density is defined as the ratio of density of the substance to the density of given reference material, which can be kerosene, water, milk, spirit, etc,. Specific gravity is the relative density which is the ratio of density of the substance to the density of the water at 4°C.

That is, $$R.D.\,(Specific\ gravity)\ of\ substance = \frac{Density\ of\ substance}{Density\ of\ water\ at\ 4^{0}C}$$

$$R.D.\ of\ substance = \frac{\dfrac{Mass\ of\ the\ substance}{Volume\ of\ the\ substance}}{\dfrac{Mass\ of\ the\ water\ at\ 4^{\circ}C}{Same\ volume\ of\ the\ water}}$$

$$R.D.\ of\ substance = \frac{Mass\ of\ the\ substance}{Mass\ of\ the\ water\ at\ 4^{\circ}C}$$

$$R.D.\ of\ substance = \frac{Mass\ of\ some\ volume\ of\ the\ substance}{Mass\ of\ equal\ volume\ of\ water\ at\ 4^{\circ}C}$$

or, $$R.D.\ of\ substance = \frac{Mass\ of\ the\ substance}{Mass\ of\ equal\ volume\ of\ water}$$

Converting mass to weight by multiplying both the numerator and denominator by acceleration due to gravity (g), we get

$$R.D.\ of\ substance = \frac{Weight\ of\ the\ substance\,(body)}{Weight\ of\ equal\ volume\ of\ water}$$

Applying Archimedes' Principle,

$$R.D.\ of\ substance = \frac{Weight\ of\ the\ substance\,(body)}{Weight\ of\ displaced\ liquid}$$

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$$\text{or, } R.D.\ of\ substance = \frac{Weight\ of\ the\ body}{Upthrust}$$

Therefore, the relative density of a solid is also defined as the ratio of the weight of the body to the upthrust.

## Activity 2.3 Calculating the relative density of a stone

**Materials required:**

A small stone, thread, spring balance, beaker partially filled with water.

### Procedure

**Step 1** ☞ Tie the stone with the thread and hang it from the hook of the spring balance as shown in Figure 2.9 (a).

**Step 2** ☞ Record the weight of the stone in air as $W_1$ =...

**Step 3** ☞ Lower the stone into the water as shown in Figure 2.9 (b).

**Step 4** ☞ Record the weight of the stone in water as $W_2$ = ......

(a) (b)

Figure 2.9

Now answer the following questions.

1. What is the upthrust acting on the stone?
2. Calculate the specific gravity of the stone.
3. Calculate the density of the stone in $kgm^{-3}$.

**Example 2.5**

A solid weighs 50 gf in air and 44 gf when completely immersed in water. Calculate (i) R.D. of the solid (ii) upthrust (iii) density of the solid in $kgm^{-3}$.

**Solution:**

$$(i)\ R.D.\ of\ a\ solid = \frac{Weight\ of\ the\ body\ in\ air}{Upthrust\,(loss\ of\ weight\ in\ water)} = \frac{50}{50-44} = \frac{50}{6} = 8.33$$

$$(ii)\ Upthrust = loss\ of\ weight = 6\ gf$$

$$(iii)\ Density\ of\ the\ solid\ is\ 8.33 \times 10^3\ kg\ m^{-3}$$

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### ii. Relative density (R.D.) of a liquid

Relative density of a liquid is the ratio of the density of the liquid to the density of water at 4⁰C.

i.e,

$$R.D.\ of\ liquid = \frac{Density\ of\ liquid}{Density\ of\ water\ at\ 4^{0}C} = \frac{Mass\ of\ some\ volume\ of\ the\ liquid}{Mass\ of\ same\ volume\ of\ water\ at\ 4^{\circ}C}$$

$$R.D.\ of\ liquid = \frac{Weight\ of\ some\ volume\ of\ the\ liquid}{Weight\ of\ same\ volume\ of\ water\ at\ 4^{\circ}C}$$

When a body is immersed in a liquid or in water, the volume of displaced liquid and the volume of displaced water are same or equal.

i.e., the volume of the displaced liquid = Volume of the displaced water.

Using Archimedes' Principle,

$$R.D.\ of\ liquid = \frac{Weight\ of\ the\ displaced\ liquid}{Weight\ of\ the\ displaced\ water} = \frac{Upthrust\ in\ liquid}{Upthrust\ in\ water}$$

$$Or\ \mathbf{R.D.\ of\ liquid} = \frac{\mathbf{Loss\ of\ weight\ of\ the\ solid\ in\ the\ liquid}}{\mathbf{Loss\ of\ weight\ of\ the\ solid\ in\ water}}$$

**Activity 2.4** **Calculating the relative density of cooking oil**

**Materials required:**

Two 250 mL beakers (one partially filled with water, and the other with cooking oil), spring balance, a solid (sinker) that is insoluble in both water and cooking oil, and thread.

**Procedure**

**Step 1** Hang the solid (sinker) by the hook of the spring balance in air, as shown in Figure 2.10 (a). Record the weight of sinker in air as $W_1$ =...

**Step 2** Next, immerse the sinker in water, as shown in Figure 2.10 (b). Record the weight of sinker in water as $W_2$ = ...

**Step 3** Then, immerse the sinker in cooking oil as shown in Figure 2.10 (c). Record the weight of sinker in oil as $W_3$ =...


Figure 2.10

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Answer the following questions using the above information.

1. What is the relative density of the cooking oil?
2. Determine the density of the oil.
3. Explain one practical application of this experiment.

**Example 2.6**

A body weighs 20 gf in air, 18.2 gf in a liquid and 18.0 gf in water. Calculate (i) the relative density of the body (ii) and relative density of the liquid.

**Solution:**

(i) $$R.D.\ of\ the\ body = \frac{Weight\ in\ air}{Loss\ of\ weight\ in\ water} = \frac{20}{20-18} = 10$$

(ii) $$R.D.\ of\ liquid = \frac{Loss\ of\ weight\ of\ the\ solid\ in\ the\ liquid}{Loss\ of\ weight\ of\ the\ solid\ in\ water}$$

$$= \frac{Weight\ in\ air - Weight\ in\ liquid}{Weight\ in\ air - Weight\ in\ water} = \frac{20-18.2}{20-18} = \frac{1.8}{2} = 0.9$$

**Example 2.7**

A solid weighs 32 gf in air and 28.8 gf in water. Find how much will it weigh in a liquid of specific gravity 0.9.

**Solution:**

$$Specific\ gravity\ of\ liquid = \frac{Loss\ of\ weight\ of\ the\ solid\ in\ the\ liquid}{Loss\ of\ weight\ of\ the\ solid\ in\ water}$$

$$0.9 = \frac{Weight\ in\ air - Weight\ in\ liquid}{Weight\ in\ air - Weight\ in\ water} = \frac{32-x}{32-28.8}$$

$$0.9 = \frac{32-x}{3.2}$$

$$x = 32 - 2.88$$

$$x = 29.12\ gf$$

$$Weight\ of\ the\ solid\ in\ liquid = 29.12\ gf$$

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**Example 2.8**

Tandin carries out an experiment to determine the relative density of a cork. He recorded the following information.

Weight of the sinker in air = 12.6 gf

Weight of the sinker in water + cork in air = 13.7 gf

Weight of both the sinker and the cork in water = 10.5 gf

Help him to find the relative density and the density of cork.

**Solution:**

*Weight of cork in air* = 13.7 - 12.6 = 1.1 gf

*Weight of cork in water* = 10.5 - 12.6 = -2.1 gf

*Since cork floats in water, upthrust on it is more than its own weight as it is made to sink with the force of the sinker. Hence weight of the cork in water is negative.*

$$R.D.\ of\ cork = \frac{Weight\ in\ air}{Loss\ of\ weight\ in\ water}$$

$$R.D.\ of\ cork = \frac{1.1}{1.1 - (-2.1)} = \frac{1.1}{3.2} = 0.34$$

*Density of the cork* = $0.34\ g\ cm^{-3}$

## Questions

1. A hot air balloon weighing 30 N is tied to the ground by a string to prevent from floating off the ground. The volume of the balloon is 20 $m^3$ and the density of air is 1.3 $kgm^{-3}$. Find:
   a. upthrust acting on the balloon. Take g = 10 $ms^{-2}$.
   b. force exerted by the rope on the balloon?
2. An iron nail floats in mercury and sinks in water. Explain why?
3. Will the weight of a kg of iron in air and the weight of a kg of cotton in air be equal? Why?
4. A solid of density 8000 $kgm^{-3}$, weighs 0.8 kgf in air. When it is completely submerged in a liquid of density 5000 $kgm^{-3}$, the weight appears to decrease. What is the apparent weight of the solid in the liquid?
5. Describe the process to determine upthrust on a body by using Archimedes' principle.

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6. A solid weighs 20 gf in air and 18 gf in water. Find the specific gravity of the solid.
7. A gold smith claims that an ornament is made of pure gold of density 19.32 $g/cm^3$. A chain made from this gold weighs 25.25 g. The apparent weight of the chain when immersed in water is 23.075 g. Using a suitable calculation, determine the purity of gold.
8. An object weighs 0.250 kgf in air, 0.150 kgf in water and 0.125 kgf in an oil. Find out the density of the object and the oil.

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## 3. Principle of Floatation

### Learning Objectives

On completion of this topic, you should be able to:

- differentiate between the terms centre of gravity and centre of buoyancy.
- describe the relationship between upthrust and the weight of a floating body.
- state the principle of floatation.
- explain some applications of the principle of floatation.

The centre of gravity (C.G.) is the point that represents the average location of all of the weight of an object. The weight of an object is distributed evenly about its centre of gravity. As a result, the downward force of an object's entire weight seems to act through its centre of gravity. For example, when you place a geometry box horizontally on your finger so that it balances, your finger is directly beneath the geometry box's centre of gravity. The weight of the box is distributed evenly about the centre of gravity.

The centre of buoyancy (C.B.) of a floating object is similar to the centre of gravity concept. When an object is partly or completely submerged in a liquid, the shape and the volume of displaced liquid is exactly the same as the volume of part of the object below the surface of liquid. The liquid displaced applies upward buoyant force on the floating object. The entire buoyant force appears to act through centre of buoyancy. The centre of buoyancy is the centre of gravity of the displaced liquid.

### A. Floating bodies

When a body is immersed in a liquid, two forces act on the body, namely:

**i. Weight of the body** – The weight of the body (W) acts vertically downward through the centre of gravity of the body (C.G.).

**ii. Upthrust** – It is the force that acts vertically upward ($F_B$) through the point known as the centre of buoyancy. The centre of buoyancy (C.B.) is the centre of gravity of the displaced liquid.

When a body is immersed in a liquid as shown in Figure 2.11, the weight of the body $W_1$ acts downward and the upthrust $W_2$ due to the liquid acts upward. Depending on the magnitude of the weight of the body and the upthrust acting on the body, following conditions exist when body immerses in the liquid.

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- If $W_1 > W_2$, then body sinks in liquid, as weight of the body is more than the weight of the liquid displaced (upthrust).
- If $W_1 < W_2$, then body floats in the liquid, as the weight of the body is less than the weight of the liquid displaced (upthrust).
- If $W_1 = W_2$, then body floats at the level of surface of the liquid, as the weight of the body is equal to the weight of the liquid displaced (upthrust). In such a case, apparent weight is zero.

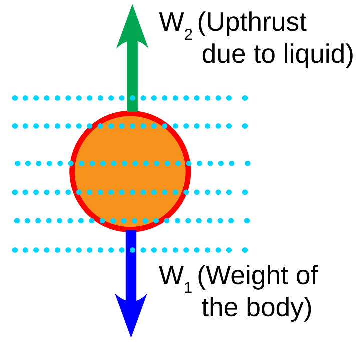


Figure 2.11

From the above cases, it is evident that for a body to float in a liquid, the weight of the floating body should be either lesser than or equal to the upthrust exerted by the liquid.

Therefore, ***the principle of floatation states that the weight of the floating body is equal to the weight of liquid displaced by the body***.

## B. Equilibrium of floating bodies

When a body is completely immersed in a liquid , its stability depends on the relative positions of the centre of gravity of the body and the centroid of the displaced volume of fluid, which is called the centre of buoyancy. The position of centre of gravity and centre of buoyancy in case of a completely submerged body are fixed. There are three types of equilibrium attained by an immersed body in a liquid.

### *Neutral Equilibrium*

A body is said to be in neutral equilibrium if the body remains in its position as soon as the force is removed. Neutral equilibrium is attained by a floating body:

- if $W = F_B$ and C.B. and C.G. are at the same point .
- if a slight displacement to the body in the clockwise direction, make body to attain new position.

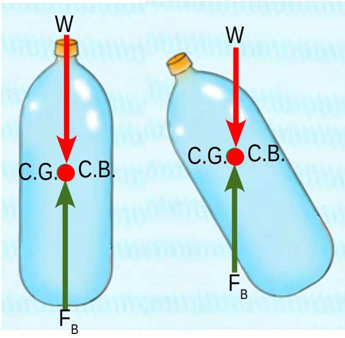


Figure 2.12 Neutral Equilibrium

### *Unstable Equilibrium*

A body is said to be in unstable equilibrium if it is not able to return to its position when slightly disturbed. When the force is removed, the object continues to move in the same direction. Unstable equilibrium is attained by a floating body:

- if $W = F_B$ ,but C.B. is below C.G.,the body is in unstable equilibrium.

- if a slight displacement to the body in the clockwise direction, gives the couple due to W and $F_B$ ,also in the clockwise direction. Thus the body does not return to its original position rather continues in the direction of displacement.

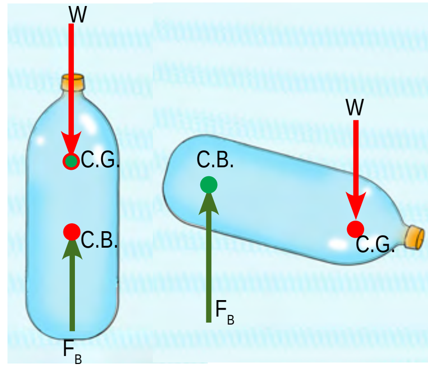

Figure 2.13 Unstable Equilibrium

***Stable Equilibrium***

We say that a body is in stable equilibrium if it is able to return to its position when slightly disturbed. This equilibrium is obtained by a body floating in a liquid if the following conditions are met.

- When $W=F_B$ and point C.B. is above C.G. , the body is said to be in stable equilibrium.
- If the body is given an angular displacement in the clockwise direction, then W and $F_B$ constitute a couple acting in the anti-clockwise direction and brings the balloon in the original position.

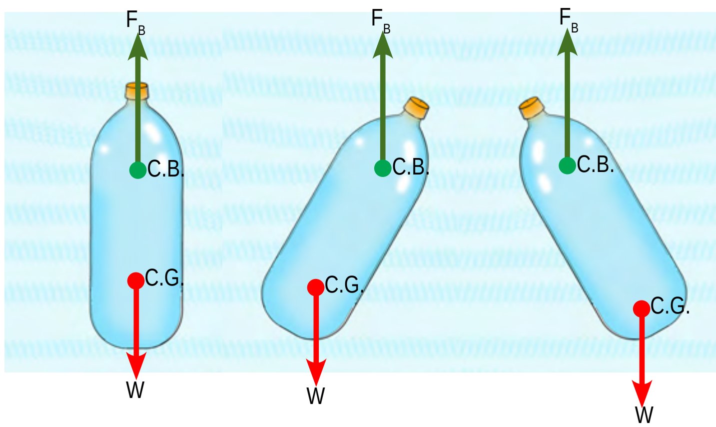

Figure 2.14 Stable Equilibrium

## C. Volume of body submerged in liquid

Consider a body of volume ***V*** and density ***D*** submerged in liquid of density ***d***. Let ***v*** be the volume inside the liquid, then

Weight of the body $W_1 = VDg$

Weight of liquid displaced (upthrust) $W_2 = vdg$

By principle of floatation

$$W_1 = W_2$$

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*i.e,* $VDg = vdg$

or, $\frac{v}{V} = \frac{D}{d}$

i.e, $\frac{\text{Volume of immersed part of body}}{\text{Total volume of the body}} = \frac{\text{Density of the body}}{\text{Density of liquid}}$

The above equation implies that if density of a body is 0.8 g/cm$^3$, then 80% of volume of body will be under water.

In the same way, the density of ice is 0.9 g/cm$^3$, that is, 90% of a given volume of the ice will be under water. For this reason, icebergs float with only a small portion of it above the sea.

The principle of floatation has relevance to our everyday life and in the physical phenomenon occurring in the environment.

1. **Submarines** - A submarine sinks by letting in water into its buoyancy tanks (ballast tanks). By doing this, the weight of the submarine increases, but the upthrust on it remains unchanged, thus it sinks. To resurface, compressed air is used to force water out of the tanks.

2. **Hot air balloon** - Balloon filled with hot air or hydrogen, weighs less than cold air that it displaces. Therefore, the upthrust is greater than its weight, and the resultant upward force on the balloon causes balloon to rise.

3. **Ship** - A ship floats on the surface of the sea because the volume of water displaced by the ship provides enough upthrust to support the weight of the ship.

   The construction of a ship is done in such a way that the overall density of the ship is lesser than the density of sea water. Therefore, the buoyant force or the upthrust acting on the ship is great enough to support its weight.

4. **Fishes** - Fishes use Archimedes' principle to float and sink in water. To rise, the fishes will fill its swim bladder (air sacs) with gases. The gases diffuse from its body to the bladder increasing volume of the body, which results in greater upthrust. To go deep in water, the fishes will empty their bladder which decreases its volume reducing the upthrust by the water.

5. **Hydrometer** - Hydrometer is an instrument used to measure the relative density of a liquid. It consists of a weighted sealed glass bulb for buoyancy, and a graduated scale. The graduated scale indicates the relative density of the liquid. In denser liquids, the hydrometer floats more. Lower the density of the substance, the further the hydrometer sinks. There are different types of hydrometer as follows:

2.15 Hydrometer

a. A lactometer (or galactometer) is a hydrometer used to test milk.
b. An alcoholometer is a hydrometer that is used for determining the alcoholic strength of liquids.
c. A saccharometer is a hydrometer used for determining the amount of sugar in a solution.
d. A thermohydrometer is a hydrometer that has a thermometer enclosed in the float section to measure the density of petroleum products like petrol, diesel, kerosene, etc,.
e. Battery hydrometer is used to estimate the concentration of the sulphuric acid solution (electrolyte) in a lead acid battery.

**Example 2.9**

Dorji immersed a body of density 0.70 g/cm³ in a liquid of density 0.80 g/cm³. Calculate the volume of the immersed part of the body.

**Solution:**

*Here, density of the body (D) = 0.70 g/cm³*

*We know, density of liquid(d) = 0.8 g/cm³*

*Let the total volume of body (V) = 100 units*

*Therefore, the volume of immersed part of the body*

$$v = \frac{D \times V}{d} = \frac{0.7\ gcm^{-3} \times 100\ units}{0.8\ gcm^{-3}} = 87.5\ units$$

*Therefore, 87.5% part of the body will be immersed in the liquid.*

**Example 2.10**

The mass of a block made of certain material is 13.5 kg. Its volume is $15 \times 10^{-3}$ m³. Will the block float or sink in water? Give a reason for your answer.

**Solution:**

$$\text{Density of the block} = \frac{mass}{volume} = \frac{13.5}{15 \times 10^{-3}}$$

$$= 0.9 \times 10^{3}\ kg\ m^{-3}\ (\text{density of water is } 1 \times 10^{3}\ kg\ m^{-3})$$

*The block floats in water, because its density is less than that of water.*

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## Summary

- Pressure is the thrust acting on a unit area.
- Pressure inside a liquid increases with increase in the depth of the liquid.
- Pressure at a point inside a liquid is same in all directions.
- Liquid pressure increases with density of liquid.
- Atmospheric pressure is the thrust exerted by a column of air on the surface of the Earth.
- A barometer is an instrument that measures atmospheric pressure.
- Aneroid barometer is small in size, and does not contain any liquid.
- Normal atmospheric pressure at the sea level is 76 cm of mercury column in the mercury barometer.
- Barometer is used to forecast weather in a given region.
- The upward force experienced by a body when immersed inside a fluid is called upthrust or buoyant force.
- Upthrust depends on the volume of the body immersed and the density of the liquid.
- The apparent weight of a body is the difference between the weight of the body and the upthrust acting on the body.
- Archimedes' Principle states that when a body is immersed partially or wholly in a fluid (liquid or gases), it experiences an upthrust, which is equal to the weight of the liquid displaced.
- Specific gravity is defined as the ratio of the density of the substance to the density of water at $4^{o}C$.
- The density of water at $4^{o}C$ is 1000 $kgm^{-3}$ or 1 $gcm^{-3}$.
- The centre of buoyancy (C.B.) is the centre of gravity of the displaced liquid.
- The principle of floatation states that the weight of the floating body is equal to the weight of liquid displaced by the body.
- Hydrometer is an instrument to measure the relative density of liquid directly and, hence the purity of the liquid.

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## Exercises

*I. Multiple choice questions.*

1. Which instrument measures pressure in gases?
   - A Manometer.
   - B Barometer.
   - C Thermometer.
   - D Anemometer.
2. The upward force of the liquid acting on a submerged object is
   - A friction force.
   - B air resistance.
   - C buoyant force.
   - D resultant force.
3. The density of liquids is measured by
   - A Manometer.
   - B Thermometer.
   - C Barometer.
   - D Hydrometer.
4. The pressure at the bottom of a glass of water is P (Density of water = 1000 $kgm^{-3}$). If the water is replaced by kerosene oil (Density = 817.5 $kgm^{-3}$) then the pressure at the bottom will be
   - A equal to P.
   - B less than P.
   - C more than P.
   - D zero.
5. Study Figure 2.15 and choose the correct statement from the following. The amount of liquid in all the containers is equal. The pressure exerted by liquid

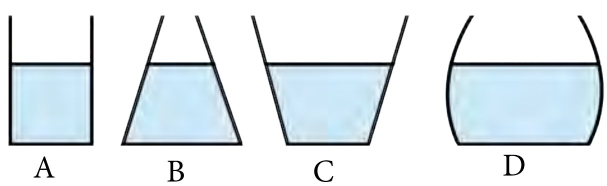


Figure 2.15

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A in container A is less than in container D.
B in container B is less than in container C.
C in all the above containers is same.
D depends on the shape of the container.

***II. Fill in the blanks.***

1. Manometer is an instrument that is used to measure pressure inside a ......................
2. The main forces acting on a body that is floating in the sea are .................. and .......................
3. The hydrometer which is used to measure the purity of milk is called ........................
4. The centre of gravity of the displaced liquid is called .....................................
5. The measurements of ................ pressure at different time interval is used to forecast weather conditions.

***III. Match the following.***

| Column A | Column B |
|---|---|
| 1. Bar | a. comparion of densities of substances. |
| 2. Lactometer | b. an instrument to measure thickness of liquid. |
| 3. Relative density | c. Principle of floatation. |
| 4. Barometer | d. a unit of atmospheric pressure. |
| 5. Buoyancy | e. hydrometer to check purity of liquid. |
| | f. measure atmospheric pressure |
| | g. tendency of liquid to make body sink. |

***IV. State whether the following statements are 'True' or 'False', and correct the false statements.***

1. If an object sinks in a liquid and floats on another liquid, it implies that the density of the second liquid is less than the first liquid.
2. The immersed volume of body in a liquid depends on density of the liquid.
3. Relative density of a body is usually expressed in $kgm^{-3}$.
4. A hydrometer sinks less in a lighter liquid.
5. The upthrust is equal to the weight of the liquid displaced by the body.

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V. *Answer the following questions.*

1. A metal block weighs 500 gf in air and 460 gf when completely immersed in water. Calculate the upthrust on the block.
2. Give reasons for the following:
   (i) Cutting is easier with sharp tools.
   (ii) Sometimes, people bleed from nose while climbing uphill rapidly.
   (iii) A body weighs less inside water.
   (iv) A balloon filled with hydrogen rises up only to a certain height.
3. A cork weighs 2.5 gf in air. When tied to a sinker, the total weight is 20 gf in water. If the sinker alone weighs 25 gf in water, find the density of the cork.
4. The atmospheric pressure at a place is 650 mm of Hg. Convert this pressure into pascals (Pa). Given, density of Hg = 13,600 $kgm^{-3}$.
5. The pressure of water on the ground floor in a building is 50,000 Pa, and at the first floor it is 20,000 Pa. Taking the density of water as 1000 $kgm^{-3}$, find the height of the first floor.
6. The normal atmospheric pressure at the sea level is 0.76 m of mercury. What would be the height of the barometer, if water is taken as the barometric liquid? Why do you think water is not used as a barometric liquid?
7. Logs sometimes float vertically in a lake because one end has become water-logged, making it denser than the other end. What is the average density of a uniform-diameter log that floats with 20.0% of its length above water?
8. What do you mean by the statement, relative density of gold is 19.3?
9. A couple of ice cubes float in a glass of water. Will the water level in the glass change when the ice cubes have melted? Explain your answer.
10. A piece of wood of mass 40 g and uniform cross-sectional area of 2 $cm^2$ floats upright in water. Calculate the length of the immersed part of the wood.
11. The total mass of ship, including the cargo on board, is 1200,000 kg.
    (i) If it floats in sea, calculate the volume of the sea water it displaces? Take relative density of the sea water = 1.03.
    (ii) If the ship enters fresh water, what mass of cargo should be unloaded, so that the ship does not sink any further? Take density of the fresh water as 1000 $kgm^{-3}$.

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3

# ENERGY

If we look around us, we can see various forms of energy. Different activities require different forms of energy. Heat is a form of energy which is used for many purposes. We cook our food using heat energy from different types of sources like firewood, LPG or electricity. Our wet clothes get dried up due to heat energy from the sun. We use heat energy from the sun or electric heater to keep us warm in winter. All these things are possible because heat energy can be transferred from one body to another. The transfer of heat energy takes place due to the difference in temperatures. Temperature is one important parameter that determines the transfer of heat energy.

## 1. Temperature

**Learning Objectives**

On completion of this topic, you should be able to:

- convert temperatures from degree Celsius to Fahrenheit and vice versa.
- convert temperatures from degree Celsius to Kelvin and vice versa.
- measure temperature of hot and cold bodies using a thermometer.
- explain the transfer of thermal energy.
- explain the term thermal equilibrium.
- relate thermal equilibrium to our day-to-day life.

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## A. Measurement of Temperature

The temperature is measured in three different scales namely Celsius or centigrade scale ( C), Fahrenheit scale ( F) and Kelvin or absolute scale (K).

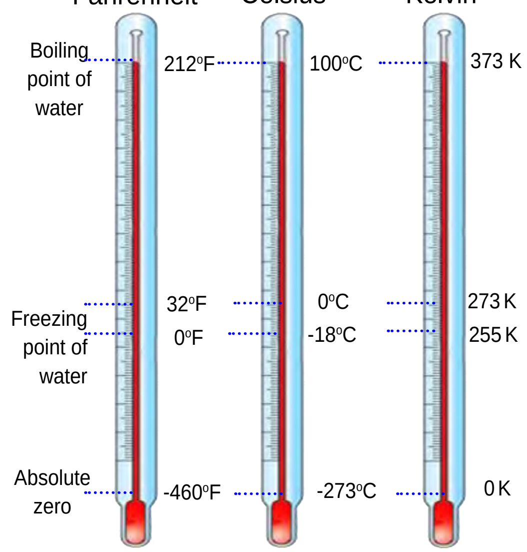

Figure 3.1

**Celsius or Centigrade scale**: On this scale, there are 100 divisions between the melting point of ice and the boiling point of water. Each division is equal to one degree Celsius (1˚C). The melting point of ice is marked as 0 degree Celsius and the boiling point of pure water is marked as 100 degrees Celsius. This scale was first devised by Anders Celsius, a Swedish astronomer.

**Fahrenheit Scale**: The melting point of ice is at 32 degrees Fahrenheit and boiling point of water is at 212 degrees Fahrenheit in this scale. The space between these two points is divided into 180 divisions. Here, each division is called one degree Fahrenheit (1˚F). This scale was first devised by German scientist Daniel Gabriel Fahrenheit.

**Kelvin or Absolute scale**: This scale is mostly used for scientific experiments as all temperatures are positive in this scale. The number of divisions between the melting point of ice and boiling point of water is same as in Celsius scale. However, in this scale, the melting point of ice is at 273 Kelvin and boiling point of water is at 373 Kelvin.

The temperature of zero kelvin is called *absolute zero*. Absolute zero is defined as the hypothetical temperature at which all the motion of the molecules stops.

### Activity 3.1 Measuring temperature of hot and cold bodies

**Work in groups.**

**Materials required:** 3 beakers, ice, tap water, hot water, three Celsius thermometers and three Fahrenheit thermometers (for each group).

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### Procedure

**Step 1** ☞ Teacher will provide three beakers filled with ice, tap water and hot water respectively on a table for each group. A Celsius thermometer and a Fahrenheit thermometer will be dipped in each beaker.

**Step 2** ☞ Students will take turn and take the thermometer reading in each beaker and record the temperature in both Celsius and Fahrenheit scales in Table 3.1 after every 5 minutes.

**Table 3.1**

| Time | Temperature of ice | | Temperature of tap water | | Temperature of hot water | |
|---|---|---|---|---|---|---|
| | ˚C | ˚F | ˚C | ˚F | ˚C | ˚F |
| 0 min | | | | | | |
| 5 min | | | | | | |
| 10 min | | | | | | |

**Answer the following questions.**

1. Which scale showed the greater value of temperature in each of the beakers?
2. What do you observe in the variation of temperature of water in second beaker (tap water)? What could be the reason for this?
3. What is the difference of temperature in Celsius scale and Fahrenheit scale in the case of ice? Can you suggest a relation between the two types of scales of temperature?

### *(i) Conversion of Temperature from degree Celsius to Fahrenheit and vice versa*

Generally, the temperature on one scale can be converted to another scale by using the following formula:

$$\frac{\text{Temperature on first scale - L.F.P.}}{\text{U.F.P - L.F.P.}} = \frac{\text{Temperature on second scale - L.F.P.}}{\text{U.F.P - L.F.P.}}$$

Here, L.F.P. stands for lower fixed point or melting point of ice and U.F.P. stands for upper fixed point or boiling point of water in the respective scales.

The lower fixed point is 0˚C and upper fixed point is 100˚C on Celsius scale. Similarly, the lower fixed point and upper fixed point are 32˚F and 212˚F respectively on Fahrenheit scale. Suppose C and F represent a particular temperature in Celsius and Fahrenheit scales respectively, then we can substitute the above formula as follows:

$$\frac{\text{Temperature in }^{\circ}C - L.F.P.}{U.F.P - L.F.P.} = \frac{\text{Temperature in }^{\circ}F - L.F.P.}{U.F.P - L.F.P.}$$

$$\frac{C - 0}{100 - 0} = \frac{F - 32}{212 - 32}$$

$$\frac{C}{100} = \frac{F - 32}{180}$$

$$\therefore \frac{C}{5} = \frac{F - 32}{9}$$

**Example 3.1**

While performing an experiment in Chemistry laboratory, Dawa found that the temperature of his solution was 47°C. How much will be the temperature of his solution in °F?

**Solution:**

$$\frac{F - 32}{9} = \frac{C}{5}$$

$$\frac{F - 32}{9} = \frac{47}{5}$$

$$F - 32 = \frac{47}{5} \times 9$$

$$F = 84.6 + 32$$

$$F = 116.6^{\circ} F$$

**Example 3.2**

On a hot summer day in Gelephu, a Fahrenheit thermometer showed a reading of 110 °F. How much is the temperature in Celsius scale?

**Solution:**

$$\frac{F - 32}{9} = \frac{C}{5}$$

$$\frac{110 - 32}{9} = \frac{C}{5}$$

$$\frac{78}{9} = \frac{C}{5}$$

$$9C = 78 \times 5$$

$$C = \frac{390}{9} = 43.3\,^{0}C$$

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### *(ii) Conversion of temperature from Celsius scale to Kelvin scale and vice versa*

If T and C represent a particular temperature in Kelvin and Celsius scales respectively, then the relation between them can be computed using the general formula as follows:

$$\frac{(Temperature\ in\ °C - L.F.P.)}{(U.F.P. - L.F.P.)} = \frac{(Temperature\ in\ K - L.F.P.)}{(U.F.P. - L.F.P.)}$$

$$\frac{C - 0}{100 - 0} = \frac{T - 273}{373 - 273}$$

$$\frac{C}{100} = \frac{T - 273}{100}$$

$$\therefore C = T - 273$$

$$Or\ \ T = C + 273$$

**Example 3.3**

The room temperature of research laboratories are usually kept at 25 °C. What would be the temperature in Kelvin scale?

**Solution:**

$$T = C + 273$$

*or,* $$T = 25 + 273$$

$$T = 298\ K.$$

**Example 3.4**

A kelvin thermometer showed a reading of 266 K at Dochula. What was the temperature at Dochula in °C?

**Solution:**

$$C + 273 = T$$

*or* $$C + 273 = 266$$

*or* $$C = 266 - 273$$

$$C = -7\ °C$$

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## B. Thermal Energy

When we heat a beaker of water and observe it carefully, we can see some changes in the motion of the water molecules. We see some air bubbles rising up in the beginning. Slowly the movement of water molecules increases and as the water starts boiling, the movement becomes more and more violent. The change in motion of water molecules is due to the change in their kinetic and potential energies. Both the kinetic and potential energies of a system together make up the *thermal energy* of a system.

In the case of gases, thermal energy is entirely due to its kinetic energy. If we supply heat to the system or body, its kinetic energy increases and hence thermal energy also increases. Similarly, if heat is removed from the system, its kinetic energy decreases thereby decreasing its thermal energy.

The thermal energy during its transfer from one body to another is called *heat*. The transfer of heat takes place due to the difference in temperatures. Whenever we leave a glass of hot milk or a cup of hot tea in open air for some time, it loses heat to the surrounding and becomes cold .This is because heat from the hot cup of tea or milk is transferred to the surrounding air until the temperature of the tea or coffee equals to that of the surrounding. So, thermal energy is always transferred from a region of higher temperature to a region of lower temperature until there is no further change in the temperature. At this stage the regions are said to be in *thermal equilibrium*.

So, two bodies are said to be in thermal equilibrium when they are at the same temperature and there is no net flow of heat between them.

### Activity 3.2 Identifying type of energy transfer

Identify the type of energy transfer in the Table 3.2:

**Table 3.2**

| Examples | Type of energy transfer |
|---|---|
| 1. Rising of warm water to the top on heating a pan of water | |
| 2. A steel spoon kept in a bowl of hot soup becomes hot after sometime | |
| 3. Formation of land breeze | |
| 4. Heat emitted by a heater | |

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**Now answer the following questions:**

1. Explain the formation of land breeze.
2. Name a type of energy transfer that does not require any medium.
3. Name a type of energy transfer that takes place mostly in solids.
4. Name a type of energy transfer that takes place mostly in fluids.

**Thermal energy always flows from a region of higher temperature to a region of lower temperature.**

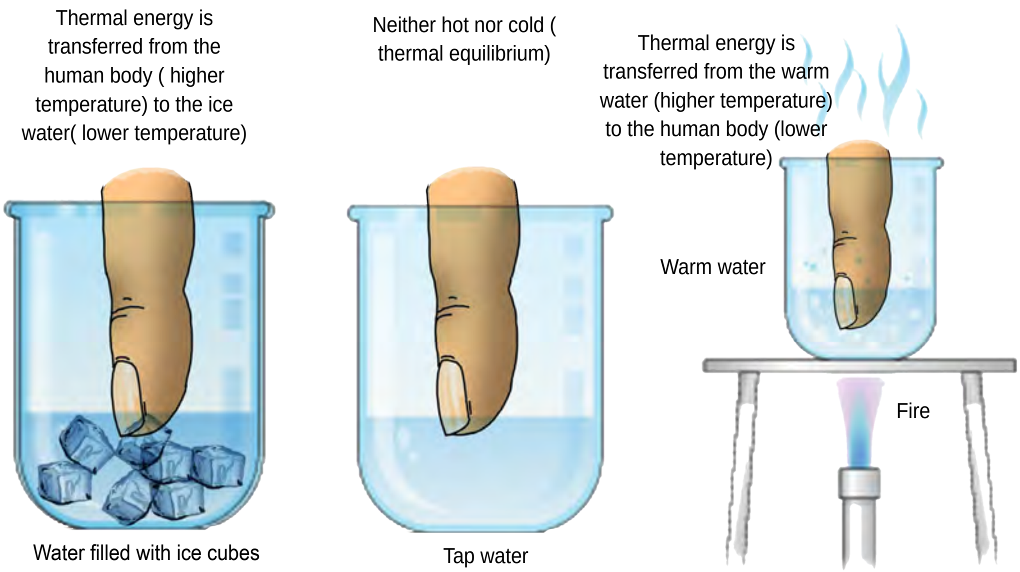


Figure 3.2

There are three modes of transfer of thermal energy. They are conduction, convection and radiation. All these three types of energy transfer take place to bring thermal equilibrium in nature.

The transfer of thermal energy is analogous to the flow of water. Water always flows from higher level to lower level. In the same manner, heat also flows from higher temperature to lower temperature. The difference in height or level determines the direction of flow of water and the difference in temperature determines the direction of flow of heat. This is the reason why we feel cold when we touch a cold body and feel hot when we touch a hot body. The temperature of ice is 0˚C and the temperature of our body is around 98.6˚F. So when we take ice in our hand, we feel cold because heat is transferred from our body to ice. Similarly, when we touch hot water, we feel hot because heat is now transferred from hot water to our body. Sometimes, when we touch some object, we may neither feel hot nor cold. This happens when the temperature of our body and the object's temperature are same or when our body and the object are in thermal equilibrium.

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## Questions

1. Dechen is suffering from high fever and doctor found her body temperature to be 103° F. If her body temperature is measured by a celsius thermometer, what would be the thermometer reading?
2. The temperature on a hot sunny day in Phuentsholing is 35°C. How much is it in Fahrenheit scale?
3. An Eskimo while working in Alaska found the temperature reading on laboratory thermometer and Fahrenheit thermometer to be equal. What is this temperature in kelvin?

# 2. Energy Transfer

### Learning Objectives

On completion of this topic, you should be able to:

- explain the uses of insulation.
- define specific heat capacity.
- compare the specific heat capacity of various substances.
- explain the term latent heat of fusion.
- explain the term latent heat of vaporisation.
- describe thermal expansion with examples.
- appreciate the role of thermal equilibrium in a system.

## A. Thermal Insulation

Flow of heat always results in thermal equilibrium. Till now we have considered the three types of heat transfer separately but in most cases all these three processes take place simultaneously. For example, when an aluminium pot filled with hot water is kept in a room, the water loses heat by conduction through the sides of the solid aluminium pot. The heat is also lost by convection as air molecules collide with the water molecules at the open surface, and by radiation as electromagnetic waves (infra-red radiations) are also emitted from the pot's surface. Proper care is taken while designing devices to prevent the transfer of heat through these means. In some cases we need to retain heat while in some we need to get rid of the heat. Therefore thermal insulation is necessary for the prevention of unnecessary transfer of heat.

### *i. Applications of thermal Insulation*

- Thermos flask is used to keep hot things hot and cold things cold for a certain period of time. It is constructed in such a way that the loss of heat energy through conduction, convection and radiation is minimised. It consists of a double-walled glass container with a wooden or plastic cork at the top. A vacuum is created in the space between the two walls of the glass container by taking out air. This prevents the loss of heat energy by conduction and convection as they require medium for transfer of heat energy. The inner surface of the walls which encloses the vacuum is silvered to reduce loss of heat by radiation. The cork at the top minimizes loss of heat due to convection.

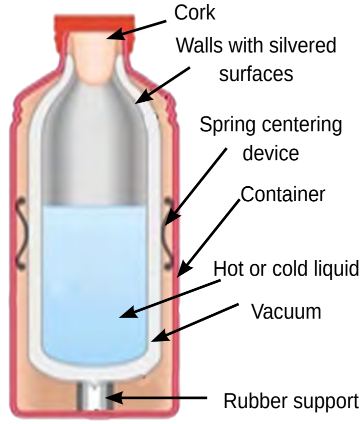


Figure 3.3 Thermos flask

Figure 3.4 Inner part of thermos flask

- In winter, in order to protect us from the cold and keep ourselves warm it is necessary to have proper insulation in our houses. We use thick curtains in our windows and also thick carpets on the floor. These are good insulators and prevent the heat from escaping.
- In cold places, the houses are usually panelled with wood. Since wood is a bad conductor of heat, it provides a good insulation from the cold outside the house. It also prevents the loss of heat from within.
- Fruits and vegetables are stored in double-walled cold storage rooms. The gap between the two walls is usually filled with air which is a good insulator. The fruits and vegetables remain fresh for a longer duration of time due to insulation of heat.
- Similarly, farmers store fruits for months by wrapping them in hay. The hay is a good insulator and prevents loss of moisture.
- The body of refrigerator is covered with thick insulating walls of fibre glass so that the heat energy from outside does not enter the refrigerator.
- Two thin blankets are warmer than one thick blanket. This is because the air

trapped in between the two blankets provides good insulation and does not allow the heat energy to escape easily to the surroundings.

- We wear woollen clothes to keep us warm in winter. Woollen clothes have trapped air in them. Since air is a good insulator, it does not allow heat to escape from within.

## B. Specific Heat Capacity

It is a common experience that when we heat cooking oil in a frying pan, it heats up very fast and smoke starts coming out of it after some time. But if we heat same amount of water, it takes more time for the water to show the same type of phenomenon. It is not only in the case of cooking oil and water but most of the substances show this difference when they are heated. If we keep iron rod and wood for same time in the hot sun and feel them after an hour, the iron rod will be much hotter than the wood. So, when same quantity of heat energy is supplied to different substances, the rise in temperature may not be same. This difference in the rise of temperature of various substances is due to the difference in one important property of the substance called *specific heat capacity*.

***Specific heat capacity*** of a substance is the amount of heat required to raise the temperature of unit mass of the substance by 1˚C. It is usually represented by the symbol 'c'.

The specific heat capacity is measured in joule per kilogramme per degree centigrade ($Jkg^{-1}{}^{\circ}C^{-1}$) or joule per kg per Kelvin ($Jkg^{-1}K^{-1}$). It is also measured in calorie per gram per degree centigrade ( cal $g^{-1}{}^{\circ}C^{-1}$). 1 calorie = 4.2 joule.

**Activity 3.3** **Comparing specific heat capacities of different substances**

**Materials required:** A bottle of milk, water, thermometer and burner.

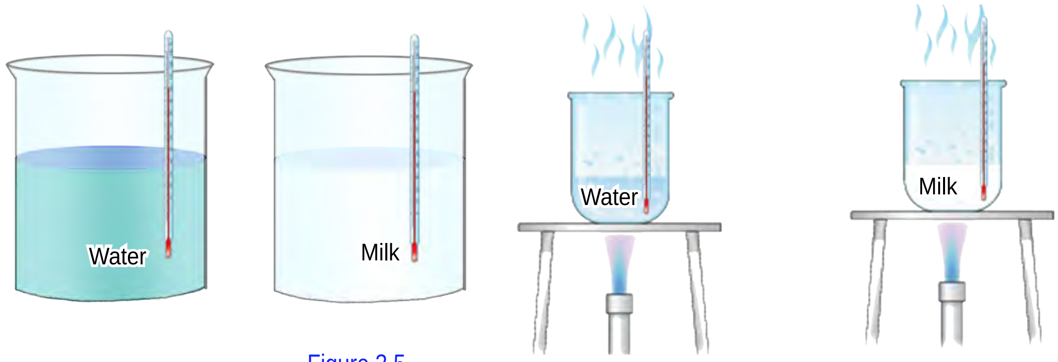


Figure 3.5

### Procedure

**Step 1** ☞ Take 100 g of milk in a beaker and record its initial temperature with the help of a thermometer.

**Step 2** ☞ Heat the milk on a burner for 10 minutes and record the rise in temperature. Remove the heat from it.

**Step 3** ☞ Take 100 g of water in identical beaker and record its initial temperature.

**Step 4** ☞ Heat the beaker of water from the same burner for 10 minutes and record the rise in temperature.

**Answer the following questions:**

1. In which case, the rise in temperature is greater?
2. From the above observation, which liquid do you think has taken more quantity of heat in 10 minutes? Why do you think so?

The specific heat capacities of different substances are different. The specific heat capacity of water is the highest of all the solid or liquid substances. Its value is 4200 $Jkg^{-1}{}^{\circ}C^{-1}$ or 1 cal $g^{-1}{}^{\circ}C^{-1}$.

### *i. Applications of high specific heat capacity of water*

Water has high specific heat capacity and takes more time to heat up as well as cool down, compared to other substances. Hence, it is put to many good uses in our day-to-day life.

i) Hot water is used in hot water bags or bottles to keep us warm during winter, because water takes longer time to lose heat due to its high specific heat capacity and hence acts as a store-house for heat.

ii) Water is used as a coolant in automobile radiators. Owing to its high specific heat capacity, it takes longer time to heat a certain amount of water than the same amount of other substances. It has the ability to absorb a large amount of heat without showing much increase in its temperature.

iii) The formation of land and sea breezes is also due to the same reason. The specific heat capacity of soil is much smaller than that of water. As a result, soil or land heats up as well as cools down faster than water. During day time, land heats up faster than the sea. The warm air above the land rises up and the cool

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air from the sea rushes in to take its place thereby causing sea breeze.

iv) Sponging is done when we have high fever. Since water has high specific heat capacity it takes away heat from our body and lowers the temperature of our body.

### ii. Calculation of heat energy gained or lost

A hot body loses heat until its temperature is in equilibrium with that of the surroundings. Similarly, a cold body gains heat from its surroundings until its temperature is in equilibrium with that of the surroundings. The amount of heat (Q) either lost or gained by a body depends on its mass (m), specific heat capacity (c) and the rise or fall in temperature (ΔT).

Hence it can be calculated by using the formula, $\mathbf{Q = mc\Delta T}$.

The rise or fall in temperature, ΔT, is the difference in the initial temperature ($T_i$) and the final temperature ($T_f$).

**Example 3.5**

Sangay found that the temperature of her aluminium container of mass 500 g fell from 50°C to 35°C. Calculate the amount of heat lost by the container. The specific heat capacity of aluminium is 900 $Jkg^{-1}°C^{-1}$.

**Solution:**

$$m = 500\ g = \frac{500}{1000}\ kg = 0.5\ kg;\ c = 900\ Jkg^{-1}\,^{0}C^{-1};\ \Delta T = 50 - 35 = 15^{\circ}C$$

$$Q = mc\Delta T$$

$$Or\ \ Q = 0.5 \times 900 \times (50\text{-}35) = 6750\ joules.$$

**Example 3.6**

Wangchuk required 4260 joules of heat to raise the temperature of 250 grams of a substance from 60°C to 90°C? What is the specific heat capacity of the substance?

**Solution:**

$$Q = 4260\ J;\ m = 250\ g = \frac{250}{1000}\ kg\ = 0.25\ kg;\ \Delta T = 90 - 60 = 30^{\circ}C;\ c=?$$

$$Q = mc\Delta T$$

$$Or,\ c = \frac{Q}{m\Delta T}$$

$$Or,\ c = \frac{4260}{0.25 \times 30}$$

$$c = 568\ Jkg^{-1}\,^{0}C^{-1}$$

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**Example 3.7**

Tashi supplied 1012 calories of heat to a piece of iron and raised its temperature from 20°C to 100°C. Calculate the mass of the iron piece. Specific heat capacity of iron is 0.11 cal/g°C.

**Solution:**

$Q = 1012\ cal;\ c = 0.11\ cal/g;\ \Delta T = 100 - 20^\circ C = 80^oC;\ m=?$

$$Q = mc\Delta T$$

$$Or,\ m = \frac{Q}{c\Delta T}$$

$$Or,\ m = \frac{1012}{0.11 \times 80}$$

$$m = 115\ g.$$

**Example 3.8**

Lhaden supplied 2000 calories of heat to 500 grams of lead at 25°C. What is the final temperature of the lead? The specific heat capacity of lead is 0.031 cal/g°C.

**Solution:**

$Q=2000\ cal;\ m=500\ g;\ c=0.031\ cal/g;\ T_i=25\ ^\circ C;\ T_f=?$

Let the final temperature = $T_f\ ^\circ C$.

$$Q = mc\ (T_f - T_i)$$

$$or,\ (T_f - T_i) = \frac{Q}{mc}$$

$$or,\ T_f - 25 = \frac{2000}{500 \times 0.031}$$

$$or,\ T_f - 25 = 129.03^\circ C$$

$$T_f = 129.03 + 25 = 154.03^\circ C$$

## *iii. Principle of Calorimetry*

When two bodies are kept in contact, heat transfer takes place from hot body to cold body till they attain thermal equilibrium. This means that the amount of heat lost by the hot body should be equal to the amount of heat gained by the cold body provided there is no loss of heat energy to the surroundings. This is called principle of calorimetry.

Therefore, as per principle of calorimetry, under ideal conditions

***Heat gained by cold body = Heat lost by hot body.***

This principle is used in measuring the specific heat capacities of substances.

## Activity 3.4 Calculating specific heat capacities of solids

**Materials required:** Copper calorimeter, a mercury thermometer, a small piece of copper ( any metal available) of about 50 g, a 250 mL beaker with water, a long pencil, a Bunsen burner , digital balance and a piece of thread.

### Procedure

**Step 1** ☞ Take a small piece of copper and find its mass with the help of a digital balance. Record its mass.

**Step 2** ☞ Take some water in a 250 mL beaker and bring it to boil by heating on a Bunsen burner. Tie the copper piece with a long thread and suspend it inside boiling water with the help of a long pencil. Do not let the copper piece touch the bottom of the beaker.

**Step 3** ☞ Take 100 mL of water in a copper calorimeter and record its temperature.

**Step 4** ☞ When the metal piece becomes sufficiently hot, record its temperature with the help of a thermometer. Take it out of the boiling water and immediately plunge into the cold water taken in the calorimeter. Do not splash the water inside the calorimeter. Cover the calorimeter with its lid and stir it gently without taking the metal piece out of the water.

**Step 5** ☞ Insert the thermometer from the hole in the lid of the calorimeter and record the highest temperature of the water inside it when it becomes steady.

**Step 6** ☞ Calculate the amount of heat gained by the water taken in the calorimeter by using the formula

***Heat gained*** $= m_1c_1(T-T_1)$, where $m_1$ is the mass of the water taken, $c_1$ is the specific heat capacity of water ,T is the final temperature of water and $T_1$ is the initial temperature of water.

**Answer the following questions:**

1. What type of metal is used in this activity?
2. What happened to the temperature of water inside the calorimeter when the metal piece was dropped into it?

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3. How much heat is lost by the metal piece?
4. How much heat is gained by the water?
5. Using the principle of calorimetry, calculate the specific heat capacity of the metal piece?
6. Define specific heat capacity in terms of the specific heat capacity of the metal used in this activity.

**Table 3.3 Specific heat capacities of some substances**

| Substances | Specific heat capacity in cal / gram˚C | Specific heat capacity in J / kg˚C |
|---|---|---|
| Water (at 20˚C) | 1.00 | 4200 |
| Ethyl alcohol | 0.58 | 2440 |
| Aluminium | 0.21 | 897 |
| Brick | 0.20 | 840 |
| Copper | 0.095 | 399 |
| Diamond (carbon) | 0.12 | 516 |
| Graphite (carbon) | 0.17 | 717 |
| Ice at 0˚C | 0.50 | 2100 |
| Crown glass | 0.16 | 670 |
| Iron | 0.115 | 449 |
| Lead | 0.031 | 129 |
| Marble | 0.21 | 880 |
| Mercury | 0.033 | 140 |
| Mica | 0.21 | 880 |

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**Example 3.9**

Pelzang dropped a red hot iron piece of mass 100 g at 120˚C into 100 g of water at 25˚C. The final temperature of the mixture is 35˚C. What is the specific heat capacity of iron?

**Solution:**

*Mass of iron piece,* $m_1 = 100\ g$

*Mass of water,* $m_2 = 100\ g$

*Initial temperature of water* $=25°C$

*Initial temperature of iron* $=120°C$

*Final temperature of mixture* $=35°C$

*Specific heat capacity of water,* $c_2 = 1\ cal/g°C$

*Specific heat capacity of iron,* $c_1 = ?$

*Heat energy lost by iron = Heat energy gained by water*

$$m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$$

$$100 \times c_1 \times (120-35) = 100 \times 1 \times (35-25)$$

$$8500 c_1 = 1000$$

$$c_1 = \frac{1000}{8500} = 0.12\ cal/g°C$$

**Example 3.10**

Tashi added 4 kg of water at 70˚C to 10 kg of water at 20˚C. Find the temperature of the final mixture provided there is no loss of heat to the surrounding.

**Solution:**

*Mass of hot water,* $m_1 = 4\ kg$

*Mass of cold water,* $m_2 = 10\ kg$

*Initial temperature of hot water* $=70°C$

*Initial temperature of cold water* $=20°C$

*Final temperature of mixture* $=?$

*Specific heat capacity of water,* $c = 4200\ J/kg°C$

*Let the final temperature of the mixture be* $x$˚C.

*Heat energy lost by hot water=Heat energy gained by cold water*

$$m_1 c \Delta T_1 = m_2 c \Delta T_2$$

$$4 \times 4200 \times (70-x) = 10 \times 4200 \times (x-20)$$

$$14x = 480$$

$$x = 480/14 = 34.29°C$$

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## Questions

1. Leki supplied 580.5 calories of heat to 150 g of substance and raised its temperature from 19˚C to 62˚C. Help her to calculate the specific heat capacity of the given substance.
2. Tandin took 300 g of water and supplied 8000 joules of heat to it. What is the change in temperature of the water?
3. When Wangmo supplied 650 joules of heat to a small piece of brass, the temperature changed from 19˚C to 45˚C. If the specific heat capacity of the substance is 130 J/kg˚C, what is the mass of brass piece taken by Wangmo?
4. A blacksmith heated 2 kg of iron piece to 120˚C in the furnace and took it out of the fire for hammering into thin sheet. The iron piece cooled down to 30˚C during the process of hammering. What was the amount of heat lost by the iron? Take specific heat capacity of iron as 450 J/kg˚C.

## C. Latent Heat

Usually when a body is heated, its temperature rises and when a body is cooled, its temperature decreases. We can see the change in temperature with the help of a thermometer. When the temperature in the thermometer increases, it means that the body is getting hotter and heat is being absorbed. Similarly, when the temperature in the thermometer decreases, it means that the body is becoming colder and the heat is being released. But the case is bit different during the process of inter-conversion of states of matter.

Suppose a piece of ice at -5˚C is heated slowly and the change in its temperature is noted with a thermometer. It is observed that the thermometer initially shows rise in temperature. But when ice begins to melt at 0˚C, the temperature remains constant in the thermometer. Although the heat is continuously supplied to the ice, the thermometer reading remains at 0˚C for some time. The temperature in the thermometer starts to increase again, only when the whole piece of ice melts completely. The heat utilised for changing the state of matter, that is from ice to water, is not detected by a thermometer. It remains hidden or latent in the body. Such kind of heat, which remains hidden and cannot be observed by a thermometer, is called *latent heat*. The amount of heat required to change the substance from solid state into liquid state without changing its temperature is called *latent heat of fusion*.

Similarly, when water is heated, its temperature increases till 100˚C. It starts to boil and the temperature remains constant. The amount of heat absorbed by the

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water to turn into steam is also not detected by the thermometer. Here, the hidden heat is called latent heat of vaporization. The amount of heat required to convert a substance from its liquid state into its vapour state without changing its temperature is known as *latent heat of vaporisation*.

The concept of latent heat can be explained with the help of kinetic theory. According to this theory, the total energy of a molecule is the sum of its potential energy and kinetic energy. The kinetic energy of a molecule depends upon its temperature whereas its potential energy depends upon the intermolecular force of attraction and the intermolecular distance. During the process of melting, the heat absorbed is utilised in increasing the distance between the molecules. In order to increase the distance between the molecules, work is done against the force of attraction between the molecules. This work done is stored in the molecules as their potential energy. As a result, there is increase in the potential energy of the molecules. Since there is no change in the kinetic energy of the molecules, the temperature of the molecules remains same. Thus the heat absorbed during fusion or melting is not shown by the thermometer.

Similarly, the heat absorbed during the conversion of solid into its vapour state is also not shown by the thermometer. This is because the absorbed heat is used in increasing the distance between the molecules and a part of it is used in doing work against the atmosphere during expansion. This increases only the potential energy of the molecules keeping their kinetic energy constant. Hence there is no increase in the temperature of the molecules.

The latent heat is normally expressed as the amount of heat absorbed or evolved per unit mass of the substance. The amount of heat required to convert unit mass of a substance from its solid state to liquid state without change of temperature is called *specific latent heat of fusion* and the amount of heat required to convert unit mass of a substance from its liquid state to vapour state without change of temperature is called *specific latent heat of vaporisation*.

Some units of specific latent heat are joule/kg or calorie/g.

**Table 3.4: List of specific latent heat of some common substances**

| Substances | Latent heat of fusion in cal/g | Latent heat of fusion in J/kg | Latent heat of vaporization in cal/g | Latent heat of vaporization in J/kg |
|---|---|---|---|---|
| Ethyl alcohol | - | - | 204 | $855 \times 10^3$ |
| Water | - | - | 540 | $2268 \times 10^3$ |
| Mercury | 3 | $12.5 \times 10^3$ | 68 | $310 \times 10^3$ |

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| | | | | |
|---|---|---|---|---|
| Ice | 80 | $336 \times 10^3$ | - | - |
| Copper | 43 | $180 \times 10^3$ | - | - |
| Paraffin wax | 35 | $146 \times 10^3$ | - | - |

### i. Effects of High Specific Latent Heat of Fusion of Ice

The specific latent heat of fusion of ice is $336 \times 10^3$ J/kg, which is quite high compared to other substances. It means that every kilogramme of ice requires 336000 joules of heat energy to melt completely into water at 0˚C.

i) The surroundings become cold when snow starts melting in winter. The snow absorbs a large amount of heat to melt into water, thereby making the surrounding cold.

ii) There is a continuous flow of rivers from the mountains because the snow on the mountains does not melt all at once due to its high latent heat of fusion.

iii) The cubes of ice are found to cool drinks more effectively than cold water at the same temperature. This is because the ice cubes absorb lots of heat from the drinks in order to melt.

### ii. Effects of High Specific Latent Heat of Vaporisation of Water

The specific latent heat of vaporization of water is very high. Its value is 2268000 J/kg.

i) The steam is used in steam engines to run the machines due to its high latent heat.

ii) Steam at 100˚C causes more severe burns than boiling water at the same temperature, due to the high latent heat of vaporization of steam. Every kilogramme of steam at 100˚C contains 2268000 joules of heat energy more than that of boiling water at the same temperature.

## Questions

1. A vessel containing water is kept on an oven. The temperature of water increases as heat is supplied to it from the oven. But the temperature stops rising when the water begins to boil. What is the reason for this? Where does the heat go then?

2. The graph given in Figure 3.6 represents the rise in the temperature of water with time as the heat is continuously supplied to it.
   i. Name the phenomenon represented by the part AB of the graph.
   ii. Name the phenomenon represented by the part CD of the graph.

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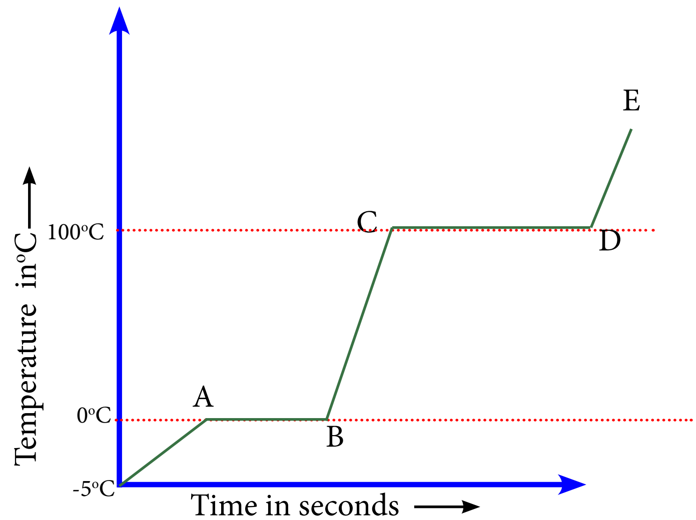


*Figure 3.6*

iii. Why are these two parts AB and CD flat in the graph?

iv. Why is the part CD longer than the part AB?

## D. Thermal Expansion of Matter

Most of the substances expand on heating and contract on cooling. On heating, both the kinetic and potential energies of atoms or molecules of the substances increase. As a result, they vibrate more and move away from each other causing expansion. The increase in the dimensions of substances on heating is called *thermal expansion*.

In winter, you might have noticed that the glass cracks quite easily when you pour hot liquid in it. This is due to the unequal expansion of the outer and inner surfaces of the glass. The inner surface expands more due to the direct contact with the hot liquid. But it takes some time for the heat to transfer to the outer surface as glass is a bad conductor of heat. Hence, the outer surface may not expand as much as the inner one.

There are three types of thermal expansion namely linear expansion, superficial expansion and volume expansion. The increase in only one dimension of the substance is called *linear expansion*. The increase in any two dimensions is called *superficial expansion* and an increase in all the three dimensions is called *cubical expansion*.

### i. Expansion in Solids

Solids are rigid with fixed shape. So, they undergo all the three types of expansion. It means that they can change all the three dimensions length, breadth and height.

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## Activity 3.5 Demonstrating expansion in solids (ball and ring experiment)

Materials required: A metal ball attached to a chain, a heating source, a metal ring and a stand.

### Procedure:

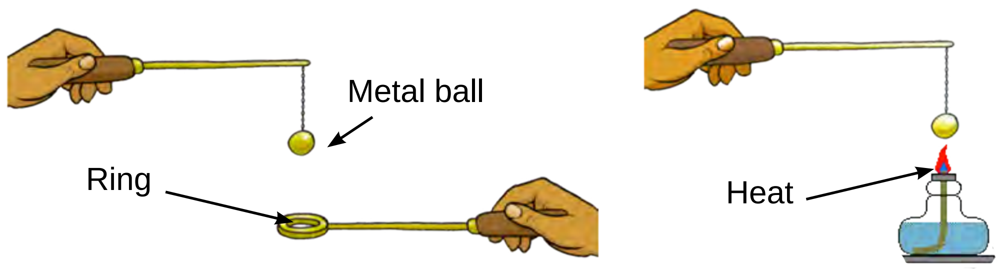


*Figure 3.7*

**Step 1** ☞ Pass the metal ball through the metal ring when it is at room temperature. Note down the observation as shown in Figure 3.7.

**Step 2** ☞ Now heat the ball with the heating source for some time and try to pass the ball again through the ring. What do you notice? Record your observation.

**Step 3** ☞ Let the metal ball cool down to room temperature and pass the ball through the ring again.

**Answer the following questions:**

1. What happens to the metal ball when it is passed through the ring at room temperature?
2. What generalization can you draw from this activity?
3. Will the ball be able to pass through the ring if both the metal ball and the ring are heated for same period of time? Give reason to support your answer.

### a. Linear Expansion

The increase in the length of a body on heating is called *linear expansion*. The linear expansion of solids is found to increase with increase in temperature, vary directly with its original length and is also dependent on the nature of material. For example when a metallic ruler is heated, its length increases.

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### b. Superficial Expansion

The increase in surface area of the solid on heating is called *superficial expansion*. It depends on the change in temperature, nature of material and the original area. For example, during hot days the metallic wires or tubes become thicker due to increase in surface area.

### c. Volume Expansion

The increase in the volume of the solids on heating is called *volume or cubical expansion*. Similarly, like linear and superficial expansions, volume expansion is affected by the change in temperature, nature of material and initial volume.

### Applications of the Expansion of Solids

There are many practical applications of expansion of solids in the fields of engineering and technology. Expansion of solids can be observed in many places around us.

1. Riveting is a process where a small metal pin called rivets are used to hold two metal plates together very tightly. The plates to be joined are placed side by side and holes are drilled in them. Then the rivets are made red hot and inserted into the holes. They are then hammered flat so that when they contract on cooling they hold the metal plates very tightly. This process is used in ship building and other constructional works.
2. Invar, an alloy of nickel and steel are used for various purposes due to its low value of coefficient of expansion.
3. Thermostat is used in making and breaking electrical circuit. It works on the principle of bimetallic strip. Bimetallic strip consists of two different metals usually brass and steel which are welded together. These two metals behave differently when there is a change in temperature. When the strip is heated the brass expands more than steel and the strip bends. Similarly, when the strip is cooled below the room temperature the brass contracts more than the steel and the strip bends in the opposite direction.
4. The telephone and electric transmission lines are usually kept loose or sagging. This is done so that they do not break when they contract in winter and expand in summer.
5. When the railway tracks are laid, small gaps are left (as shown in figure 3.8) between the successive rails to keep room for expansion. The large numbers of rails are joined together with the help of fish plates as shown in the diagram. The

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holes of the bolts are elongated to keep some space for the movement of the bolts during expansion and contraction. But this is not much in use these days.


Figure 3.8

Nowadays, the rails are welded together to make long continuous lengths of railway tracks. Concrete are used instead of wooden slippers and clamps are much stronger. As usual the rails will expand and contract but they cannot move as they are firmly fixed. So, the ends of the rails are overlapped so that they can move during expansion or contraction. This type of welded rails gives a smoother ride to the trains than the olden type of rails.

6. Metal bridges expand during summer and contract during winter. The bridges are mostly fixed at only one end and the other end is placed on rollers as shown in Figure 3.9, so that they can move freely when the bridges contract or expand. If this is not done then they may produce cracks due to expansion and contraction.

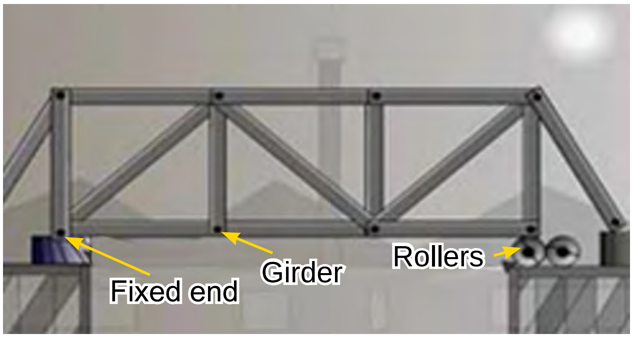


Figure 3.9

The spaces for expansion are kept along the length of the span of the bridges too. This is done by keeping small gaps filled with pitch between the small sections of the bridges.

7. Metal pipes which carry hot water or steam also expand and contract. They usually have bends in them to keep allowances for their expansion. They can easily change their shape during expansion and contraction.

### ii. Expansion in Fluids

Like solids, liquids and gases also expand. Fluids do not exhibit linear and superficial expansion. The expansion in fluids is generally much more than in the solids. Examples are expansion of mercury or alcohol in thermometer, increase in volume when water changes into ice, hot air balloons, etc.

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The mass of a substance is the product of its volume and density. The mass of substance remains constant at all temperatures. The volume of substance changes with change in temperature which results in change in density of the substance. The variation of density in the case of solids is not significant in comparison to that of liquids and gases.

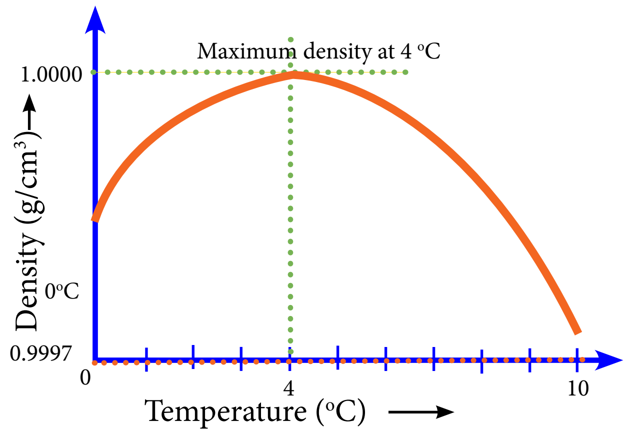

Figure 3.10

Generally all the substances expand on heating and contract on cooling but water behaves differently. Water expands beyond 4˚C on heating and its density decreases due to increase in its volume. But on cooling, the decrease in the volume of water and increase in its density occurs only till 4˚C. When the water is cooled below 4˚C, its volume increases and its density decreases again. This abnormal behaviour of water between 4˚C and 0˚C is called *anomalous expansion of water*.

So, the density of water is maximum at 4˚C and its value is 1000 $kgm^{-3}$ or 1 $gcm^{-3}$.

Some of the effects of expansion of fluids are observed in following cases:

*a. Bursting of water pipes in cold places.*

In cold places like Haa, Paro, Bumthang, water pipes usually burst in winter when the temperature falls below freezing point. At this temperature water in the pipes freezes and expands causing pipes to crack. This is because water in the pipes gets frozen at this low temperature and expands exerting an enormous force. Since there are no spaces kept for this expansion, the water pipes burst thereby causing leakage. In order to avoid this, the water pipes are usually covered with some insulating material so that the water does not freeze.

*b. Breaking of rocks.*

The anomalous expansion of water is also responsible for the breaking of rocks and weathering of soil. When the water in the small gaps in the rocks freezes during night time due to fall in temperature below freezing point, a large amount of force is exerted. As a result, some parts of the rock may break off.

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*c. Survival of fishes*

In winter in some very cold places, the temperature of the surrounding falls below freezing point. At this temperature the surfaces of ponds, lakes and rivers start freezing. The water at the surface freezes but the water below the surface does not freeze. Hence the fishes can survive even when the temperature of the surroundings falls below freezing point in winter.

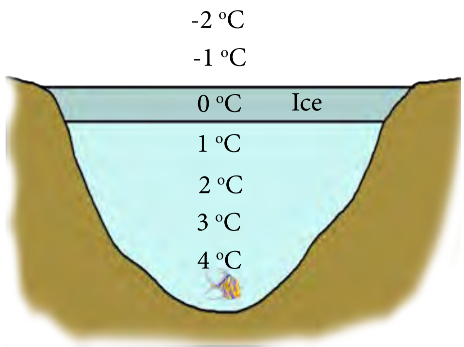


**Figure 3.11**

## Questions

1. A metal ring of certain mass is heated from 25˚C to 100˚C. What changes do you observe in its (i) volume, (ii) mass, (iii) density and (iv) diameter?
2. We usually pour hot water to loosen the tight-fitting metal cap of a glass bottle. Explain.
3. Padma observed that the level of mercury inside the thermometer rose when she touched its bulb with her fingers and as soon as she removed her fingers the level of mercury was found to go down. What could be the reason for this behaviour of mercury inside the thermometer?
4. Study Figure 3.12 carefully and answer the following questions:

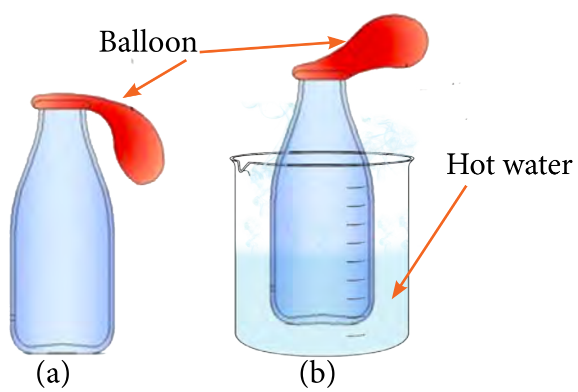


**Figure 3.12**

a. What happened to the balloon in Figure 3.12 (b)?

b. Which property of gases is demonstrated by the balloon in Figure 3.12(b)?

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## Summary

- The temperature is measured in three different scales namely Celsius or centigrade scale ( C), Fahrenheit scale ( F) and Kelvin or absolute scale (K).
- Temperature can be converted from one scale to another scale of temperature.
- Thermal energy is the sum of potential and kinetic energies of the bodies.
- When two bodies are in thermal equilibrium, there is no net flow of heat between them.
- Heat always transfers from a region of higher temperature to a region of lower temperature.
- There are three modes of heat transfer namely conduction, convection and radiation.
- Thermal insulation is necessary for the prevention of unnecessary transfer of heat.
- Specific heat capacity of a substance is the amount of heat required to raise the temperature of unit mass of the substance by 1˚C. It is measured in $Jkg^{-1}{}^{\circ}C^{-1}$ or ($Jkg^{-1}K^{-1}$) or cal $g^{-1}{}^{\circ}C^{-1}$.
- Water has many useful applications due to its high specific heat capacity.
- Specific latent of fusion is the amount of heat required to convert unit mass of a substance from its solid state to liquid state without change of temperature.
- Specific latent heat of vaporisation is the amount of heat required to convert unit mass of a substance from its liquid state to vapour state without change of temperature.
- The increase in the dimensions of substances on heating is called thermal expansion.
- There are three types of thermal expansion namely linear expansion, superficial expansion and volume expansion.
- Solids exhibit all the three types of thermal expansion while liquids and gases exhibit only volume expansion.
- Thermal expansion has many applications in our day-to-day lives.

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## Exercises

**I. *Fill in the blanks.***

1. The Kelvin scale of temperature is mostly used for______________.
2. The length of 1 degree division in Celsius scale is equal to ______________ division in Fahrenheit scale
3. The vacuum in a thermos flask reduces heat loss by _______________ and _____________.
4. Small gaps are left in between the rails of a railway line to keep room for ____________________________.
5. We use water as ____________ in motor car radiators because water has high _____________.

**II. *State whether the following statements are 'True' or 'False' and correct the false statements:***

1. Temperature is the quantity which determines the direction of flow of heat.
2. There is more number of divisions between lower fixed point and upper fixed point in Kelvin scale than in Celsius scale.
3. There is always some flow of heat in thermal equilibrium.
4. Liquids and gases undergo all the three types of thermal expansion.
5. There is a change in temperature during the inter-conversion of different states of matter.

**III. *Match the items of Column A with correct answers of Column B.***

| Column A | Column B |
|---|---|
| 1. Sum of potential energy and kinetic energy | (a) Superficial expansion |
| 2. No flow of heat energy | (b) Cubical expansion |
| 3. Specific heat capacity | (c) Thermal energy |
| 4. Increase in area | (d) $Jkg^{-1}$ |
| 5. Increase in volume | (e) Thermal equilibrium |
| | (f) $Jkg^{-1}{}^{\circ}C^{-1}$ |
| | (g) Latent heat |

**IV. *Multiple Choice Questions.***

1. Sonam was provided with a Fahrenheit thermometer and was asked to identify the lower fixed point and upper fixed point in the thermometer. The lower fixed point and the upper fixed point in the thermometer are

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A 0˚F and 100˚F respectively.

B 32˚F and 132˚F respectively.

C 32˚F and 212˚F respectively.

D 273˚F and 373˚F respectively.

2. Deki heated water in a bucket for taking bath. After sometime she found that her water was at the temperature of 60˚C. The temperature of the water in kelvin scale is

A 213 K.

B 323 K.

C 333 K.

D 373 K.

3. On a cold winter day, Phuntsho observed that plastic chair was colder to touch than a wooden chair in his classroom. Which property is demonstrated by the plastic chair and wooden chair in the above situation?

A Latent heat.

B Specific heat capacity.

C Thermal expansion.

D Thermal contraction.

4. Vegetables and fruits are usually kept in cold storage rooms in order to keep them fresh for a longer time. These cold storage rooms have

A thick walls.

B double walls.

C thin walls.

D transparent walls.

5. The amount of heat absorbed or evolved by a body depends upon its mass , specific heat capacity and

A final temperature.

B initial temperature.

C average temperature.

D difference in temperature.

6. When we feel cold, our body

A is in thermal equilibrium with the surrounding.

B temperature never remains constant.

C gains heat from the surrounding.

D loses heat to the surrounding.

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7. The latent heat of vaporization is measured in J/kg. It depends upon
   A mass.
   B volume.
   C initial temperature.
   D final temperature.
8. When an iron cuboid is heated, there is increase in
   A only its length.
   B its length and breadth.
   C its length, breadth and height.
   D none of its sides.
9. The water pipes burst in winter due to
   A expansion and contraction of water pipes.
   B expansion of water pipes.
   C contraction of water.
   D abnormal expansion of water.
10. If a certain mass of water is cooled slowly from 15˚C to 0˚C, its volume
   A decreases.
   B increases.
   C first decreases and then increases.
   D first increases and then decreases.

V. *Answer the following questions.*

1. Name the different types of temperature scales?
2. Explain thermal equilibrium.
3. What do you mean by thermal insulation?
4. What do you mean by lower fixed point and upper fixed point in a thermometer?
5. The temperature on a cold winter day in Gasa is 29˚F. How much is it in Celsius and Kelvin scales?
6. Obtain the temperature at which the reading in Fahrenheit scale is double of that in Celsius scale.
7. Find the temperature when the degrees of the Celsius scale will be one-fifth of the corresponding degrees of the Fahrenheit scale.
8. If you dip your hand in cold water after having dipped in warm water, will you feel the water colder than it actually is? Support your answer with a

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reason.

9. In summer, it is cooler in the ground floor than in the top floor of a building. It is because the warm air rises up due to convection. Why does warm air rise up?
10. How much heat is necessary to warm 500 g of water from 20˚C to 65˚C?
11. The heat required to raise 3 kg of copper from 0˚C to 10˚C raises 1 kg of lead from 10˚C to 100˚C. If the specific heat capacity of copper is 0.095 cal/g$^0$C, find the specific heat capacity of lead.
12. Study the specific heat capacities of substances given in table 3.5 and answer the following questions.

Table 3.5

| Substances | Specific heat capacity in cal/g˚C |
|---|---|
| Copper | 0.095 |
| Gold | 0.032 |
| Concrete | 0.21 |
| Olive oil | 0.43 |
| Platinum | 0.032 |

(a) If all the substances given are heated for the same duration of time, which substance will be heated to a maximum temperature?

(b) When 344 calories of heat are supplied to 40 g of a substance, there is a rise in its temperature by 20˚C. Identify the substance.

13. Some powdered naphthalene was taken in a test tube and heated on a hot water bath. The rise in temperature was recorded with a thermometer. It was observed that the naphthalene started melting at 80˚C. Draw a temperature-time graph for the process described above.
14. A kg of iron and a kg of lead, both at 100˚C, are kept on a block of ice each. After some time it is observed that iron has melted more ice than lead. Why?
15. Hot bags filled with hot water takes longer time to cool. Why?
16. One of the ends of bridges is usually fixed with a roller and the other end is fixed. Explain why this is done while constructing the bridges?
17. When 4050 joules of heat were applied to 150 g of aluminium, the final temperature was 50˚C. What was the initial temperature? Take specific heat capacity of aluminium as 900 J/kg˚C.
18. Karma poured 8 kg of cold water at 23˚C to 2 kg of hot water in a bucket and the final temperature was 37˚C. What was the initial temperature of the hot water? Neglect the heat lost to the surrounding.

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4

# ELECTRICITY & MAGNETISM

In today's world, electricity plays an important role in our life. Think of energy used at home, office, shops, and factories. We are so much dependent on electricity that without it we cannot do most of the work. At home, we use it for lighting our houses, cooking, heating, washing and many other purposes; in offices, to run computers, copiers, printers, etc.; and in factories, to run heavy machines. Electricity is a form of energy that is convenient to use, as this form of energy is easily stored in so many forms.

Similarly, magnetism has also been put to many uses. Magnets are the main parts of most of the electrical appliances that we use in our homes and schools. There are magnets in our phones, radios, televisions, refrigerators, fans, washing machines, juice blender, and so on.

Many years ago, electricity and magnetism were considered as two separate entities. Hans Christian Oersted, and then later Michael Faraday proved the interdependence between electricity and magnetism.

In this chapter, we shall study more on these two topics, their relationship, and their applications in our life.

## 1. Electromagnetic Effects

### Learning Objectives

On completion of this topic, you should be able to:

- explain the term alternating current (a.c.).
- explain the term direct current (d.c.).
- demonstrate that a force is exerted on a current-carrying wire in a magnetic field.
- describe the working of simple d.c. motors.
- carry out an experiment to exhibit electromagnetic induction.

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## A. Alternating Current and Direct Current (a.c. and d.c.)

If you look at different electrical appliances at home, their voltages are usually marked in terms of a.c. (alternating current), or d.c. (direct current). For example d.c. is marked on appliances like batteries, mobile chargers, music players, etc. and a.c. on appliances like rice cooker, curry cooker, water boiler, television set, etc. These markings represent the type of electric current that the appliances operate on. In other words, the appliances marked d.c. should not be connected directly to a.c. source.

*Direct current* is the current which flows only in one direction as shown in figures 4.1 and 4.2. The polarities of its source remain same throughout the flow of current. Its sources are dry cells, acid or alkali batteries, rectifiers, etc. There are two types of direct current depending upon their source. The direct current that is taken from the sources like dry cell and batteries has constant magnitude (as shown in Figure 4.1). But the d.c. from rectifier does not have constant magnitude (as shown in Figure 4.2). Its magnitude varies continuously with time but its direction remains same.

An *alternating current* is the current, which changes its magnitude continuously with time, and reverses its direction after regular interval of time. Accordingly, the polarities of its source also reverse periodically. It is represented by a curve as shown in Figure 4.3. The magnitude of alternating current fluctuates between a minimum value zero and a maximum value ($I_0$) in both the directions. In the Figure 4.3, one crest and one trough make one cycle or one oscillation of an alternating current.

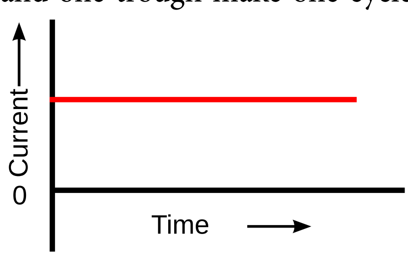


**Figure 4.1**

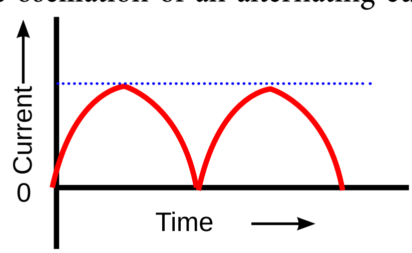


**Figure 4.2**

Thus, when an alternating current completes one cycle, its magnitude becomes maximum in positive direction (crest) as well as in negative direction (trough), and returns to zero.

The total number of cycles completed by a.c. in one second is called its frequency. The frequency of a.c. used in our household appliances is usually 50 Hz. This means that bulbs in our household go off 100 times in a second. It takes place so fast that our visual senses are not able to realise it. It is due to the *persistence of vision* of our eyes, which means that the image of any object remains in our eye for only about $\frac{1}{16}$th of a second. So, the fluctuating current seems to be continuous to our eyes.

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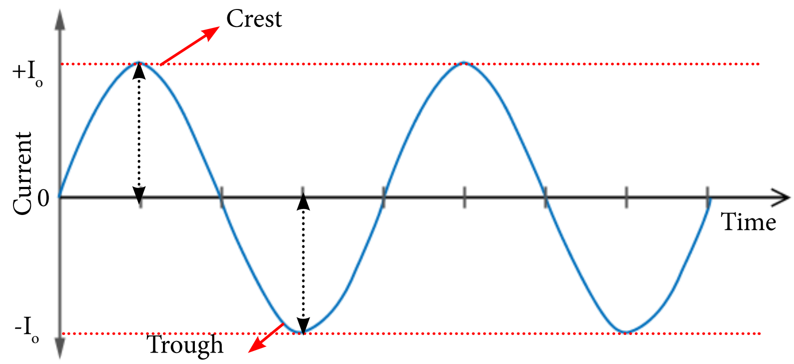


*Figure 4.3*

The alternating current also becomes maximum twice in a cycle, and this maximum value of a.c. is called peak value($I_0$) of a.c.

The d.c. and a.c. sources are represented by the symbols as shown in Figure 4.4.

The circuit diagrams for d.c. and a.c. are shown in Figure 4.5.

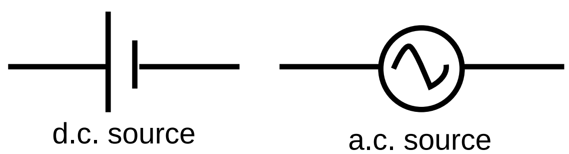


*Figure 4.4*

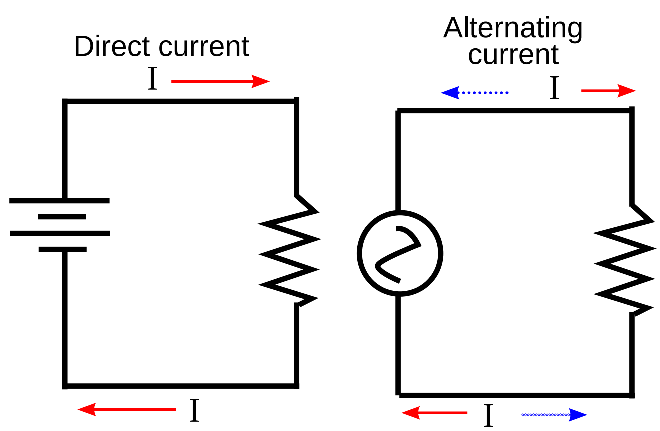


*Figure 4.5*

## B. Force on a current carrying conductor placed in a magnetic field

Hendrik A. Lorentz observed that a moving charged particle experiences force in a magnetic field. This force is called Lorentz force. Figure 4.6 shows a charged particle q, moving with a velocity v in a uniform magnetic field of strength B. Suppose the charged particle is moving at an angle 'θ' with the direction of magnetic field. The magnitude of Lorentz force experienced by this charge can be calculated by using the formula,

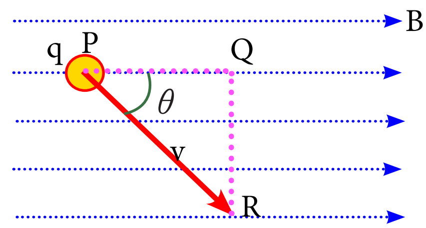

*Figure 4.6*

$$F = qvB\sin\theta = qvB \times \frac{QR}{PR}$$

Similarly, a conductor carrying current also experiences force when placed in a magnetic field. The magnitude of the force experienced by a current carrying conductor depends upon the strength of the current passing through the conductor, length of the conductor, the strength of the magnetic field and the orientation of the conductor with respect to the magnetic field. The conductor does not experience any force when it is placed parallel to the magnetic field.

The direction of the force experienced by the current carrying conductor placed in a uniform magnetic field can be determined by using the Fleming's left hand rule. It states that 'if the thumb, first finger and second finger of left hand are stretched at right angle to each other, then if the first finger indicates the direction of the magnetic field and the second finger the direction of current, the thumb will indicate the direction of motion(force) on the conductor'.

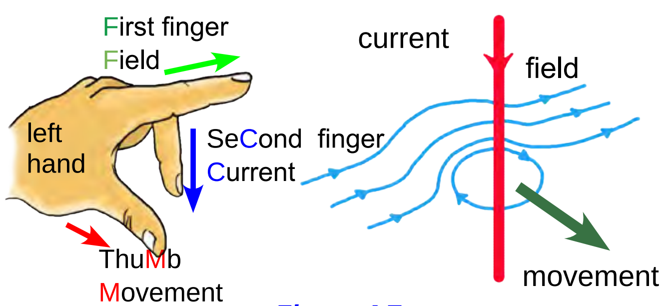

*Figure 4.7*

| **Activity 4.1** | **Investigating force on a current carrying conductor placed in a magnetic field** |
|---|---|

Teacher demonstrates the working of Barlow's wheel to the class.

**Materials required:** Barlow's wheel, mercury, battery eliminator, connecting wires and switch.

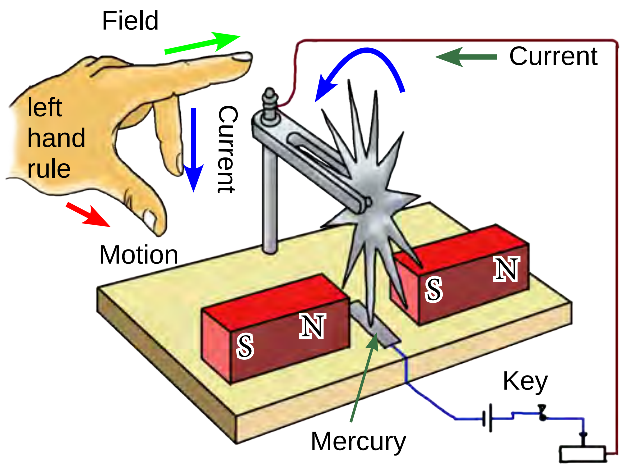


*Figure 4.8*

## Procedure

**Step 1** Teacher sets up the circuit as shown in Figure 4.8 without mercury in the space provided in the board. The voltage is kept at 4 V. Observe the movement of the wheel when the key is closed.

**Step 2** Teacher adds mercury in the space provided in the board. Observe the direction of movement of the wheel when the key is closed.

**Step 3** The teacher reverses the polarity of the d.c. source. Observe the direction of movement of the wheel when the key is closed.

**Step 4** The teacher increases the current by increasing the voltage in the battery eliminator to 6 V. Observe the speed of movement of the wheel when the key is closed.

**Answer the following questions:**

1. What is the function of the battery eliminator?
2. What are the uses of mercury and switch in the experiment?
3. What is the purpose of the wheel?
4. What is the difference between the observations in Step 2 and Step 3? What can you conclude from here?
5. What happens to the speed of the wheel in Step 4? What can you conclude from here?
6. What makes the wheel rotate?
7. What is the function of the magnet?

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### i. Simple direct current (d.c.) motor

A d.c. motor is a device, which converts the direct current into the mechanical energy. It works on the principle that, a current carrying conductor placed in a uniform magnetic field experiences force.

A simple d.c. motor consists of the following main parts as shown in Figure 4.9:

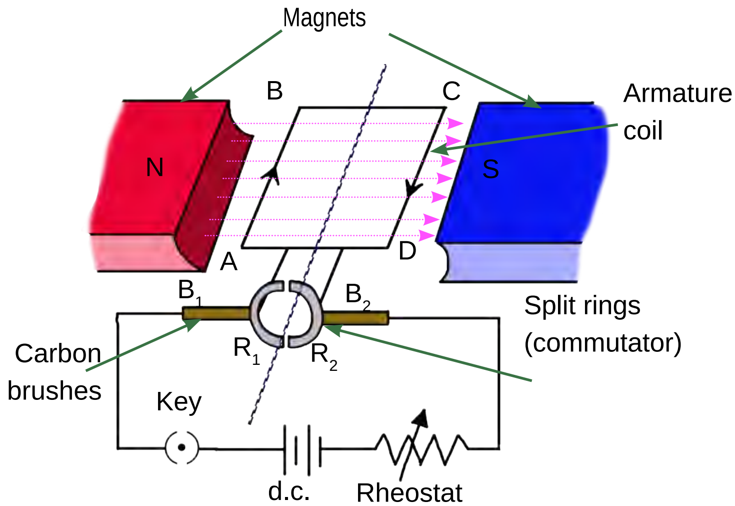


*Figure 4.9*

- **Armature coil**: It consists of several turns of insulated copper wire wound over a soft iron core. It is placed between the poles of two strong magnets and is mounted on an axle.
- **Magnet**: It consists of two poles of magnets such that it provides uniform magnetic field directed from north pole to south pole.
- **Commutator** : It consists of split rings ($R_1$ and $R_2$) welded with ends of armature coil. The split rings rotate along with the armature coil.
- **Brushes**: Two carbon brushes ($B_1$ and $B_2$) are kept in contact with the two split rings. They are not welded to the split rings and they do not rotate along with the split rings.

Consider the plane of the armature coil in horizontal position and parallel to the magnetic field. Let brush $B_1$ be connected to positive terminal and $B_2$ to negative terminal of the battery. When the current flows through the armature coil along the direction shown in the Figure 4.10(a), the arms BC and AD do not experience any force as they are parallel to the magnetic field. The arms AB and DC experience equal forces, but in the opposite directions.

According to Fleming's left hand rule, arm AB experiences inward force and the arm DC experiences outward force. So, they constitute a clockwise couple and make

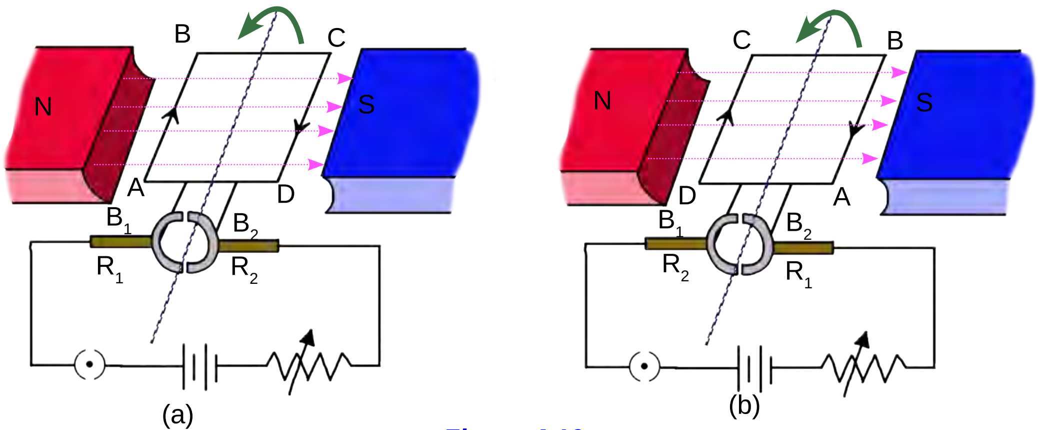


*Figure 4.10*

the armature coil rotate about its axle. When the armature coil completes half the cycle of rotation, the arms AB and DC interchange their positions. In this position brush $B_1$ is in contact with split ring $R_2$ and brush $B_2$ is in contact with split ring $R_1$. Now according to Fleming's left hand rule, the arm AB experiences outward force and DC experiences inward force. In this manner, the armature coil continues to rotate in the same direction as long as it remains connected to d.c. source.

## Activity 4.2 Making a simple electric motor

A sample of simple electric motor is given in figure 4.11. Make your own model of electric motor from the materials available around you and answer the following questions:

**Answer the following questions:**

1. List down the materials that you have used for constructing your model of d.c. motor.
2. Increase the number of cells in your model and observe the speed of the coil. What happens to the speed of the coil?
3. Take a stronger magnet and observe the speed of the coil. What happens to the speed of the coil?
4. Increase the number of turns in the coil and observe its speed. What is your observation?

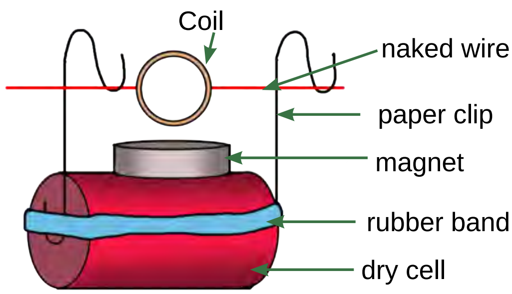


*Figure 4.11*

5. What conclusions can you draw about an electric motor from this activity?

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## C. Electromagnetic Induction

In 1820, Oersted discovered that when current flows through a conductor, it produces magnetic field around the conductor. This phenomenon of producing magnetism from electricity is called *magnetic effect of current*. Later in 1831, Michael Faraday discovered that the current is developed in a conductor due to change in the magnetic field. This phenomenon of inducing current from magnetism is called *electromagnetic induction*.

### (i) Faraday's Laws

Faraday's laws for electromagnetic induction are stated as follows:

- Whenever there is a change in the number of magnetic field lines passing through the conductor, voltage is induced in it.
- The magnitude of induced voltage is directly proportional to the rate of change of the magnetic field through the circuit.

The experiments in activity 4.3 are called Faraday's experiments of electromagnetic induction. In these experiments, there is no cell or battery connected in the circuit. The current is induced in the circuit due to the change in the magnetic field through the coiled wire as shown in Figure 4.12.

When the magnet is moved towards or away from the stationary coiled wire, the number of magnetic field lines passing through the coiled wire changes. This change

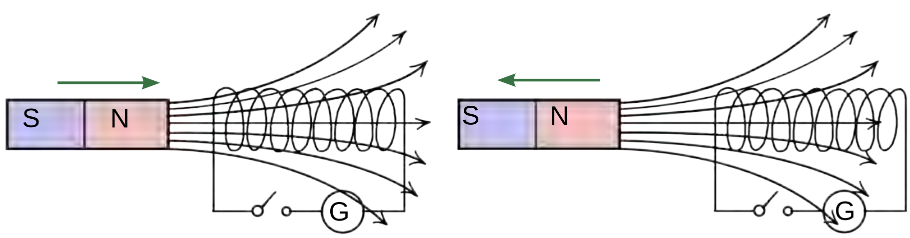


**Figure 4.12**

in the magnetic field lines induces voltage across the conductor and the current developed starts flowing through it. This is the principle of electric generators or dynamo.

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## Activity 4.3 Demonstrating electromagnetic induction

**Materials required**: Insulated copper wire, a strong magnet, galvanometer, key and connecting wires.

### Procedure

**Step 1** Take a coil of copper and connect its ends to the terminals of a galvanometer as shown in Figure 4.13.

**Step 2** Keep the coil stationary and move a magnet towards and away from the coil. Observe the deflection in the galvanometer.

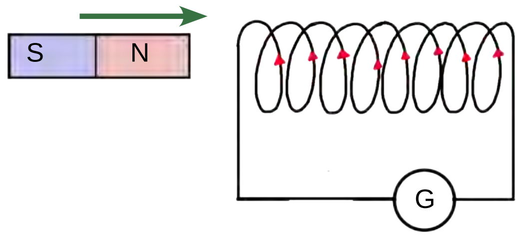


**Figure 4.13**

**Step 3** Keep the magnet stationary and move the coil towards and away from the magnet. Observe the deflection in the galvanometer.

**Step 4** Keep both the magnet and the coil stationary and observe the deflection in the galvanometer.

**Step 5** Move the magnet slowly near the coil and observe the deflection in the galvanometer. Then move the magnet faster than before and observe the deflection in the galvanometer.

**Answer the following questions:**

1. What conclusions can you draw from steps 2 and 3? Which law is verified in these steps?
2. Which law is verified in step 4?
3. Which law is verified in step 5?

### *(ii) Lenz's Law*

The direction of an induced voltage is determined by using Lenz's law.

Lenz's law states that the direction of induced voltage is such that it tends to oppose the very cause which produces it.

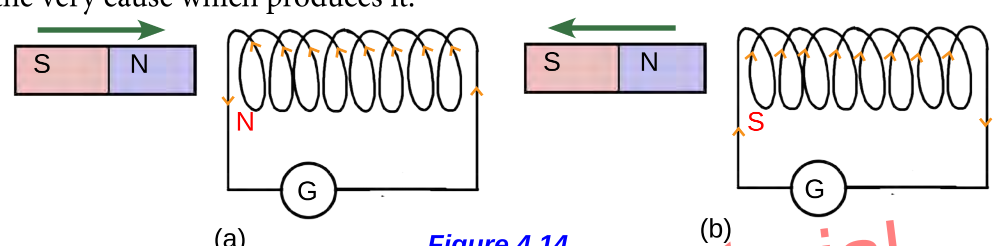


**Figure 4.14**

When the north pole of a magnet is moved towards the coil, the face of the coil closer to the magnet acquires north polarity so as to repel the motion of the magnet towards it. As a result, the direction of an induced current is counter-clockwise in that face when viewed from the side of the magnet. Similarly, when the north pole of the magnet is moved away from the coil, the face closer to the magnet acquires south polarity, and tends to oppose the motion of the magnet by attracting it. In this case, the induced current flows in the clockwise direction in the face closer to the magnet.

## Activity 4.4 Demonstrating Lenz's law

**Materials required**: Bar magnet, copper coil, galvanometer and connecting wires.

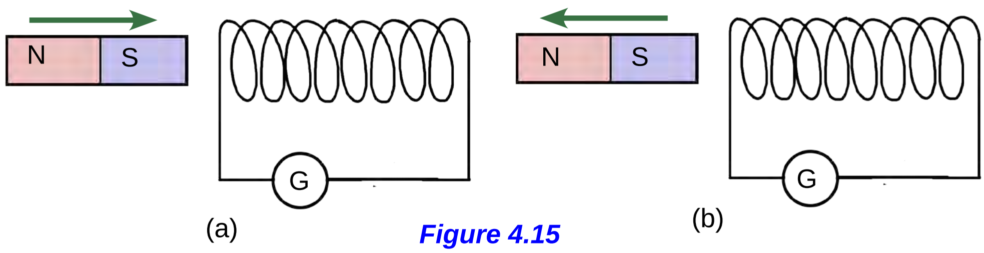


*Figure 4.15*

### Procedure

**Step 1** ☞ Set up the apparatus as shown in Figure 4.15.

**Step 2** ☞ Move the south pole of the magnet towards the coil as shown in Figure 4.15 (a). Observe the direction of deflection in the galvanometer.

**Step 3** ☞ Move the south pole of the magnet away from the coil as shown in Figure 4.15 (b). Observe the direction of deflection in the galvanometer.

**Answer the following questions:**

1. If the current flows along the direction of deflection of the galvanometer, predict the direction of current in the face of the coil closer to the south pole of the magnet in steps 2 and 3.
2. If clockwise direction of current indicates south pole and counter-clockwise indicates north pole of a magnet, predict the polarity of the face of the coil closer to the bar magnet in steps 2 and 3. What do you conclude from here?

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## Questions

1. Yangchen uses dry cells in her torch. Name the type of current used in her torch and give one more example of such appliance which works on the same type of current.
2. How alternating current differs from direct current? Which one do you prefer and why?
3. Name four electrical appliances that work on electric motors.

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# 2. Electric Charge

## Learning Objectives

On completion of this topic, you should be able to:

- explain charging of an insulating material by friction.
- describe the forces of attraction between unlike charges (positive and negative charges), and forces of repulsion between like charges.
- detect charge on bodies using gold leaf electroscope.
- explain electric current in terms of the flow of charge carried by free electrons in metals, or ions during an electrolysis.
- calculate steady current, charge and time using the formula $I=dq/dt$.

All the substances around us are made up of tiny particles called atoms. Each atom consists of three main subatomic particles, namely electrons, protons, and neutrons. Protons and neutrons are present in the nucleus of the atoms. Electrons revolve around the nucleus in their orbits. Electrons are negatively charged, protons are positively charged and neutrons are neutral. There are equal number of electrons and protons in a neutral atom. Hence the net charge of an atom is zero.

## A. Charging by Friction

Most of the substances acquire the property of attracting other substances by rubbing with other substances.

When two different substances are rubbed against each other, electrons from the atoms of one of the substances get transferred to the other substance. The substance, which loses the electrons becomes positively charged, and the other substance, which gains the electrons becomes negatively charged. Some of the examples of charging by friction are given below.

- When a piece of amber is rubbed with wool, the amber takes away some electrons from the wool and becomes negatively charged. Hence, it is found to attract other neutral substances like dust particles, bits of straw, etc. The wool also acquires equal charge on losing electrons, but of opposite nature.
- A plastic comb after being rubbed several times with dry hair is found to attract small bits of paper. In this case, the plastic comb gains electrons from the dry hair and acquires a negative charge.
- A glass rod rubbed against silk cloth loses electrons to the silk cloth. Hence, it

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is found to acquire positive charge, and the silk cloth acquires equal amount of negative charge on gaining electrons.

Figure 4.16

- When a woollen cap is taken off the head, the cap takes away some electrons from your hair and becomes negatively charged. The hair losing some electrons becomes positively charged. Each strand of hair getting similar charge tends to repel away from each other and they stand up.

In all the above cases the bodies acquire charge due to friction.

There are two types of charges developed on bodies due to friction namely positive charge and negative charge. These types of charges depend on nature of substances.

## Activity 4.5 Investigating forces between different types of charges

**Materials required:** Two pith balls lined with thin aluminium foil, cotton thread, glass rods, silk cloth, plastic ruler and woollen cloth.

### Procedure

**Step 1** ☞ Take the two pith balls and attach each of them with cotton thread. Suspend them from a rigid support as shown in Figure 4.17.

**Step 2** ☞ Rub two glass rods with silk cloth, and touch them with the two pith balls. Observe the pith balls.

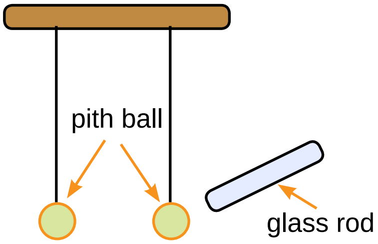


Figure 4.17

**Step 3** ☞ Now, rub one glass rod with silk cloth and rub plastic ruler with a woollen cloth. Touch one pith ball with glass rod and other pith ball with plastic ruler, and observe.

**Step 4** ☞ Next, touch one pith ball with glass rod rubbed with silk cloth, and the other ball with uncharged glass rod. See what happens.

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**Answer the following questions:**

1. What happened to the pith balls when they were touched by the glass rods? Why?
2. What happened to pith balls when touched by charged glass rod and charged ruler? Why?
3. What happened to the pith balls in step 4? Why?
4. Why should we test the pith balls with uncharged glass rod and charged glass rod in step 4?
5. Predict two most favourable conditions for this experiment.

The charges on two glass rods rubbed with silk cloth are of similar nature, while the charge on the plastic ruler is of the opposite nature. So, it can be concluded from this experiment that "*like charges repel and unlike charges attract each other.*" It is seen that not only unlike charges, but charged body and uncharged body also attract each other. Therefore, attraction between two bodies cannot confirm that they are of opposite nature, but repulsion between two bodies confirms that they are of similar nature.

## *(i) Electroscope*

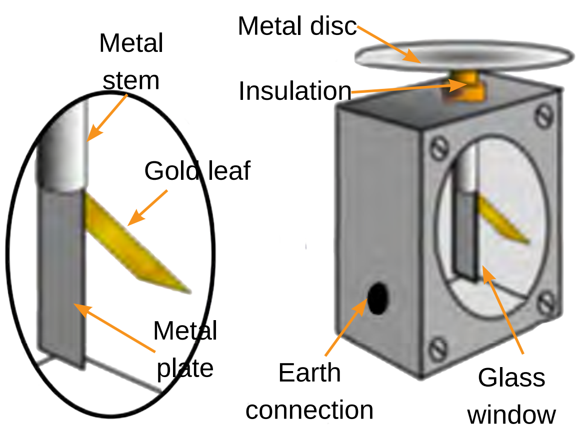

***Figure 4.18***

Electroscope is an instrument used to detect the presence of charges on bodies, and also to identify the nature of charges.

Gold leaf electroscope (Figure 4.18) is a suitable instrument for detecting charges as well as identifying the nature of charge on a body. It consists of metal disc, glass window and gold leaves. A metallic rod is passed into the box through an ebonite plug. At one end of the rod, two thin leaves of gold foil are attached. The gold leaves are sealed inside the metallic case, so that no external disturbances like air current can affect its working. The other end of the metallic rod is projected out of the metallic box and attached to a circular metallic disc. The metallic case is connected to the earth, in order to leak off any charges developed on it due to friction.

An uncharged gold leaf electroscope has closed gold leaves. When a neutral or uncharged body is made to touch the metal disc of the electroscope, the two thin gold leaves remain closed, showing that no charge has been transferred to them. But, if a charged body is made to touch the disc, the leaves open up or diverge. This

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is because both the leaves get similar charges and they repel from each other. This phenomenon of charging electroscope is called *charging by conduction*.

We can also charge an electroscope by bringing a charged body close to its metallic disc without touching it. This phenomenon is called *charging by induction*. As shown in Figure 4.19, when a positively charged body is brought near the disc, an opposite charge is induced on the disc and similar charge is induced at the other end of the metallic rod inside the electroscope. The nature of charge on the charged body can also be determined by using this induction method.

## Activity 4.6 Detecting charges using gold leaf electroscope

Materials required: Gold leaf electroscope, plastic comb, glass rod, silk cloth, woollen cloth and plastic ruler.

**Procedure:**

**Step 1** ☞ Rub the plastic comb on your dry hair several times, and touch the metallic disc of the electroscope with it. Observe the gold leaves.

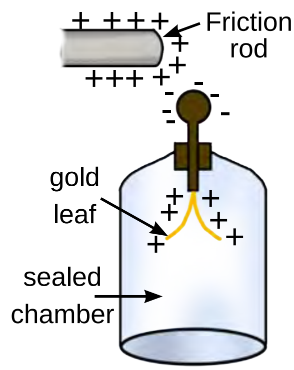


*Figure 4.19*

**Step 2** ☞ Next, rub glass rod with the silk cloth for some time and take the glass rod close to a metallic disc. Observe the divergence of the gold leaves.

**Step 3** ☞ Rub plastic ruler on your sweater or woollen cloth several times, and take it near to the metallic disc. See the divergence of the leaves.

**Step 4** ☞ Take an uncharged glass rod or plastic ruler near the electroscope. Observe the gold leaves and note down your observations.

**Answer the following questions:**

1. What happened to the gold leaves when it is touched with plastic comb rubbed with your hair?
2. What happened to the gold leaves when glass rod is taken near the leaves? Why?
3. What happened to the gold leaves when plastic ruler is taken near the leaves?
4. What happened to the gold leaves when an uncharged glass rod or plastic ruler is taken near the electroscope?
5. What conclusions can you draw from the observations in steps 2, 3 and 4 regarding the properties of charged bodies?

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## B. Electric current

When charges are at rest on charged bodies like insulators, it is called *static electricity*. If two charged bodies, one positively charged and other negatively charged, are connected with a metallic wire, the charges flow from the negatively charged body to the positively charged body. This flow of charges through the wire constitutes an electric current. The flow of charges from one end of the conductor to the other end through the motion of charged particles is called *current electricity*.

In metallic conductors like copper, aluminium, silver, gold, etc, the current is conducted by the flow of electrons. In these conductors, outermost electrons in their atoms are loosely held, and hence, they can freely move in the conductor. Electrons flow from a region of lower potential to a region of higher potential when the ends of the metallic conductor are connected to d.c. or a.c. source.

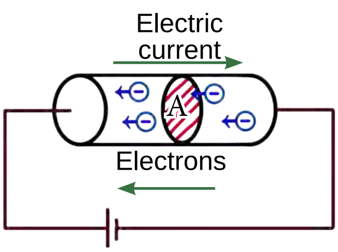

Figure 4.20

In liquid conductors like copper sulphate solution, dilute sulphuric acid, ammonium chloride solution and hydrogen chloride solution, the charge carriers are the positively and negatively charged ions. These liquid conductors are also called *electrolytes*. When two conducting rods called *electrodes* are immersed inside these electrolytes, potential difference is created between the two electrodes. One electrode becomes positively charged and is at a higher potential. This electrode is called *anode*. The other electrode becomes negatively charged and it is at a lower potential. This electrode is called *cathode*. When the two electrodes are connected to external resistance through a metallic conductor the positively charged ions move towards the cathode, and the negatively charged ions move towards the anode within the electrolyte. The electrons flow from cathode to anode through the conductor. Therefore electric current flows from cathode to anode within the electrolyte and from anode to cathode through the conductor. This process of passing current through liquid electrolytes is called *electrolysis*.

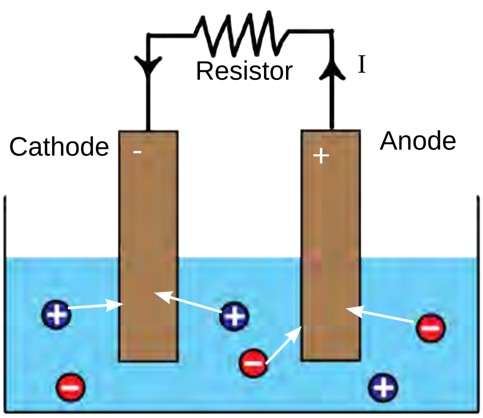

Figure 4.21

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### (i) Measurement of electric current

Electric current is the rate of flow of charges across any cross-section of a conductor. It is represented by symbol ***I*** and it is measured in amperes (A). The unit of charge is coulomb.

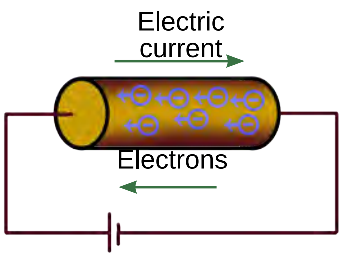


*Figure 4.22*

Suppose a total charge Q flows through a cross-section A of the conductor given in Figure 4.22 in time t, then

$$Current\,(I) = \frac{Charge\,(Q)}{Time\,(t)} \quad \text{..... equation (1)}$$

If ***n*** number of electrons flow through a cross-section ***A*** in time ***t***, then

$Q = ne$ where, ***e*** is the charge on an electron.

The formula for the current will be

$$I = \frac{Q}{t} = \frac{ne}{t} \quad \text{..... equation (2)}$$

The equations (1) and (2) give the formula for calculating a steady current. *Steady current* is a direct current having constant magnitude.

**Example 4.1**

A charge of 1 coulomb passes through a cross-section of a conductor in 2 seconds. Calculate the current flowing through the conductor.

**Solution:**

$Q = 1\ C$

$t = 2\ seconds$

$I = \frac{Q}{t}$

$I = \frac{1}{2} = 0.5A$

**Example 4.2**

Pema lights a torch for 3 seconds during power cut and a current of 0.2 A flows through the torch filament. What is the magnitude of charges passing through the filament?

**Solution:**

$$I = 0.2\ A;\ t = 3\ seconds;\ I = \frac{Q}{t}$$

$$Q = I \times t$$

$$Or,\quad Q = 0.2 \times 3$$

$$Q = 0.6\ C$$

**Example 4.3**

A current of 0.4 ampere flows through a copper wire when a charge of 2 coulomb passes through a point in certain time. What is the time taken by the charge to pass through that point in the wire?

**Solution:**

$$Q = 2\ C$$

$$I = 0.4\ A$$

$$t = \frac{Q}{I}$$

$$Or,\ t = \frac{2}{0.4} = 5\ seconds$$

## Questions

1. Differentiate between static electricity and electric current.
2. Show the types of charges developed at the ends of the conductor A given in the Figure 4.23. Name the phenomenon.
3. How can a charged object attract a neutral object?
4. How much charge passes through a lamp of 3 A in 30 seconds?
5. Calculate the number of electrons passing through a wire in one second, if the wire carries a current of 6.4 A. The charge on each electron, e = $1.6 \times 10^{-19}$ C.

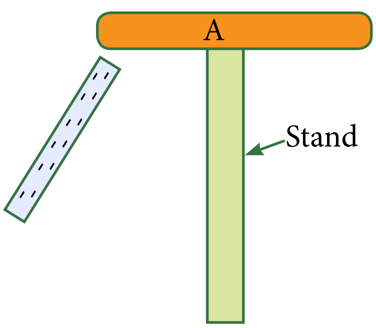


Figure 4.23

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## Summary

- There are two types of current, namely direct current (d.c.) and alternating current (a.c.).
- Direct current is the current, which flows in only one direction, and the alternating current is the current, which changes its magnitude continuously with time and reverses its direction after regular interval of time.
- The Lorentz force is the force experienced by a moving charged particle in a magnetic field.
- A current carrying conductor experiences force when placed perpendicular to a uniform magnetic field.
- The direction of the force experienced by a current carrying conductor in magnetic field is determined by Fleming's left hand rule.
- A d.c. motor is a device, which converts the direct current into the mechanical energy.
- A simple d.c. motor consists of four main parts, namely armature coil, magnet, split rings and brushes.
- An e.m.f. or voltage is induced when a conductor cuts magnetic field lines and when the magnetic field through a coil changes.
- The direction of an induced voltage is determined by Lenz's law.
- Most of the substances acquire charges due to friction.
- Like charges repel and unlike charges attract each other.
- An electroscope is an instrument used to detect and identify the nature of charges.
- A gold leaf electroscope can be charged by the methods of conduction and induction.
- The charge carriers are electrons in metallic conductors, and ions in electrolytes.
- Electric current is the rate of flow of charges across any cross-section of the conductor.

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## Exercises

*I. Fill in the blanks.*

1. The current drawn from a dry cell is ____________ current.
2. When a glass rod is rubbed with silk, the silk acquires ____________________ charge due to the _____________ of electrons.
3. D.C. motor converts electrical energy into _________________energy.
4. A charged body always ____________________ an uncharged body.
5. The direction of flow of electrons is ____________________ to the direction of electric current.

*II. Match the items of Column A with correct answers of Column B.*

| Column A | Column B |
|---|---|
| i. Electroscope | a. Direction of induced magnetism. |
| ii. Fleming's left hand rule | b. Direction of induced current. |
| iii. Faraday's experiments | c. Moving charges. |
| iv. Lenz's law | d. Gold leaves. |
| v. Lorentz force | e. d.c. motors. |
| | f. Electromagnetic induction. |
| | g. Stationary charges |

*III. State whether the following statements are 'True' or 'False'. Correct the false statements.*

1. Direct current consists of crests and troughs.
2. A current carrying conductor placed in a uniform magnetic field experiences force in any orientation.
3. The induced voltage exists in the circuit so long the change in the magnetic field continues.
4. The charge carriers in electrolytes are electrons.
5. In charging by induction, the nature of charge acquired by the conductor is same as that of charging body.

*IV. Multiple Choice Questions*

1. If a current varies continuously from zero to a maximum value and changes its direction periodically then the current is

   A direct.

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B steady.

C alternating.

D repetitive.

2. A child rubs a plastic ruler on her hair and brings near small bits of paper. The bits of paper are then attracted to the ruler. Which of the following best explains the result?

   A Paper is charged due to induction.

   B Paper is always attracted towards plastic.

   C Paper is naturally a negatively charged material.

   D Paper is naturally a positively charged material.

3. Copper sulphate solution, ammonium chloride solution and dilute sulphuric acid are liquid conductors. They conduct electric current due to the movement of

   A neutrons.

   B electrons.

   C protons.

   D ions.

4. Karma uses a piece of silk cloth to rub a plastic comb. The comb then becomes positively charged because it

   A loses protons.

   B gains protons.

   C loses electrons.

   D gains electrons.

5. An electrical device that converts electrical energy into mechanical energy is

   A d.c. dynamo.

   B d.c. motor.

   C transformer.

   D electroscope.

6. Suppose a gold leaf electroscope is positively charged. An unknown charged body is brought near its metallic disc and the divergence of its gold leaves was found to decrease. The nature of charge on the charged body is

   A neutral.

   B positive.

   C negative.

   D both positive and negative.

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7. When a strong magnet is moved near a copper coil,
   - A there is no effect on the copper coil.
   - B voltage is induced across the copper coil.
   - C copper coil is attracted towards the magnet.
   - D copper coil is repelled away from the magnet.
8. When the number of electrons passing through a cross-section of a conductor increases, the electric current through the conductor
   - A decreases.
   - B increases.
   - C remains same.
   - D first increases and then decreases.

V. *Answer the following questions.*

1. Norbu's mobile phone battery was very low. When he searched for his charger, he found that he had forgotten to take his mobile phone charger with him. He had two thin copper wires with him. Can he use these wires to charge his mobile phone by inserting them directly to the socket? Why?
2. How does the electroscope show that it is charged?
3. What is the basic principle of Barlow's wheel? What will happen to the rotation of Barlow's wheel, if the poles of the magnet are interchanged?
4. What is the function of brushes in d.c. motor?
5. What do you mean by electromagnetic induction? Under what condition is this phenomenon possible?
6. State Faraday's laws of electromagnetic induction.
7. Pema draws a current of 0.5 ampere from an electrolyte. What is the magnitude of charge flowing through it in 2 minutes?
8. How many electrons are passing through a point in a copper wire in 2 seconds when the wire carries a current of 1 ampere? Given that the charge on each electron, e =$1.6 \times 10^{-19}$ C.
9. A charge of 10 coulomb passes through a cross-section of a conductor in 20 seconds. What is the magnitude of current flowing through it?
10. In Figure 4.24, a current of 0.3 A flows through the conductor CD, and a charge of 4 C passes through a cross-section AB of the conductor. Find the time taken by the charge to pass through AB.

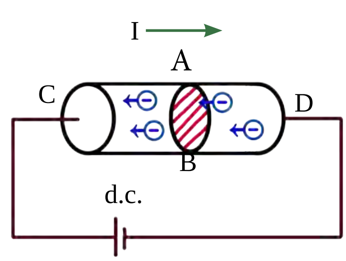

*Figure 4.24*

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5

# Refraction & Dispersion of Light

Light travels in a straight line. This property of light is true as long as the light continues to travel in the same medium. When light travels from one transparent medium to another transparent medium of different densities, it results in the bending of light. This phenomenon of bending of light ray when it passes from one medium to another is called refraction of light.

When a ray of white light passes through a prism, it not only bends but also splits up into seven different colours of light. This phenomenon of splitting of white light into its constituent colours is called dispersion of light.

## Learning Objectives

On completion of this topic, you should be able to:

- describe refraction through glass slab.
- determine the refractive index of a glass block.
- discuss refractive index of different coloured light through a prism.
- explain dispersion.
- explain total internal reflection.
- discuss the applications of total internal reflection.

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## A. Refraction of light

### Activity 5.1 Investigating refraction of light

Complete the ray diagram in Figure 5.1 and label incident ray, refracted ray, angle of incidence and angle of refraction.

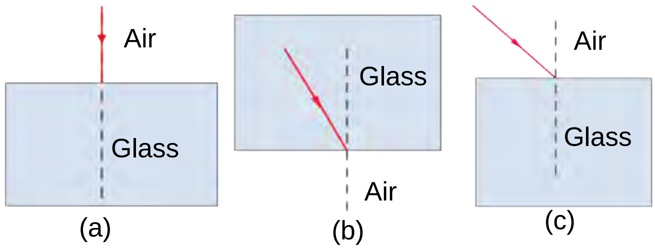


*Figure 5.1*

**Answer the following questions.**

1. Is glass denser or rarer medium as compared to air?
2. What will happen to the velocity of light ray when it passes from glass to air?
3. What happens to the light when it is incident normally on the surface of the glass slab?
4. Copy and complete the following.

   When light travels from optically denser medium to optically rarer medium, it bends _______________ from the normal, and when the light travels from optically rarer medium to optically denser medium, it bends ________________ the normal.

## B. Refraction of light through a glass slab

Figure 5.2 shows a rectangular glass slab PQRS. A ray of light AB is incident at the surface PQ. MN is the normal to the surface PQ. The ray AB enters from air to glass at the surface PQ, so it bends towards the normal MN and travels along BC inside the glass slab. Similarly, the ray suffers refraction at the surface RS. $M_1N_1$ is the normal to the surface RS. The ray BC passes from glass to air at the surface RS, so it bends away from the normal $M_1N_1$. The ray AB is the incident ray, BC is the refracted ray and CD is the emergent ray. The incident ray, refracted ray and the normal lie on the same plane WXYZ. The $\angle$ ABM is the angle of incidence $\angle$ i, $\angle$ NBC is the angle of refraction $\angle$ r and $\angle$ $N_1$CD is the angle of emergence $\angle$ e. The angle of incidence $\angle$ i is equal to the angle of emergence $\angle$ e. Thus, the incident ray AB is parallel to the emergent ray CD.

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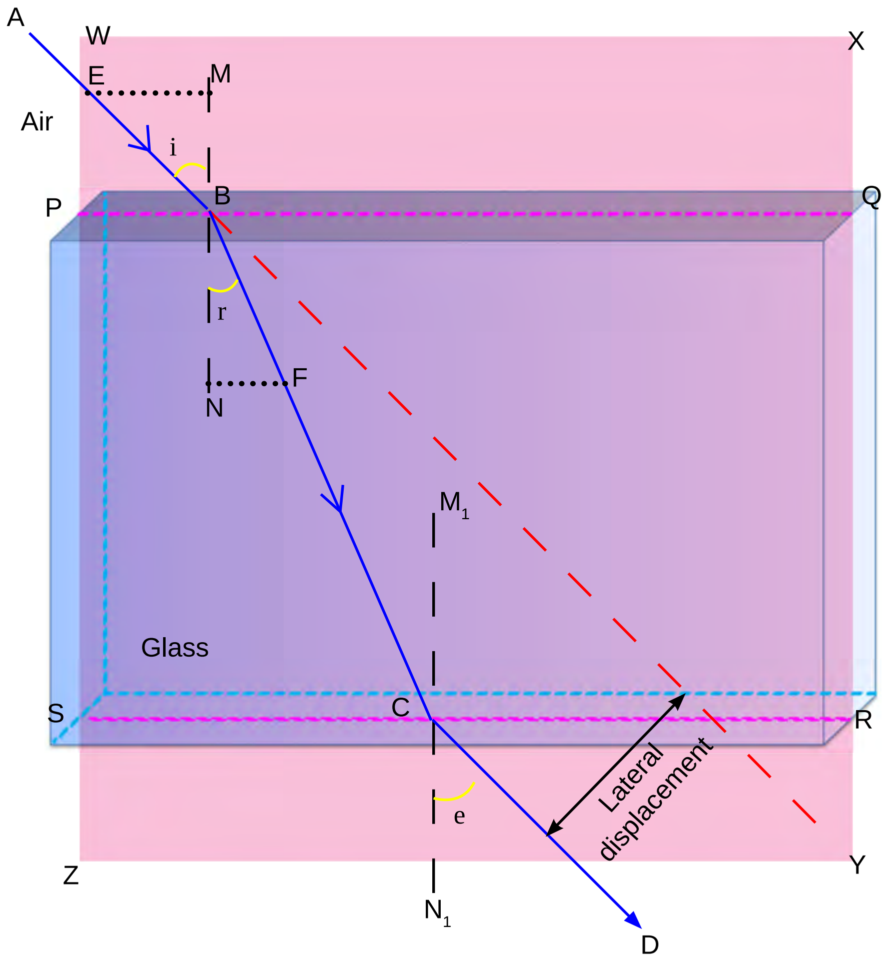


*Figure 5.2 Refraction through glass slab*

## C. Laws of Refraction

The refraction of light obeys the following two laws of refraction.

1. In Figure 5.2, the incident ray lies on plane WXYZ . The refracted ray BC, normal NM and normal $N_1M_1$ and the emergent ray CD can never be on a different plane. So, the first law of refraction states that the incident ray, the refracted ray, emergent ray and the normal lie on the same plane.

2. The refractive index of a medium is calculated by comparing the velocity of light in the first medium to the velocity of light in second medium.

   In Figure 5.2, the light rays travel from air (first medium) to glass (second medium). Therefore, the refractive index of glass can be calculated by comparing the velocity of light in vacuum (or air) and in glass.

$$Refractive\ index\ of\ glass = \frac{velocity\ of\ light\ in\ air\,(or\ vacuum)}{velocity\ of\ light\ in\ glass}$$

However, it is practically very difficult to record the velocity of light in different media. Therefore, the velocity of light in air and the velocity of light in glass can be represented by ratio of the sides of the right angled triangles EMB and BNF as in Figure 5.2.

$$\text{Therefore, } Refractive\ index\ of\ glass = \frac{(\frac{EM}{BE})}{(\frac{NF}{BF})}$$

But, $\frac{EM}{BE}$ = Sin i (sine function of angle of incidence) and

$\frac{NF}{BF}$ = Sin r (sine function of angle of refraction)

$$\text{Therefore, } Refractive\ index\,(\mu) = \frac{sin\ i}{sin\ r}$$

The second law of refraction states that the ratio of the sine of angle of incidence to the sine of the angle of refraction bears a constant equal to the refractive index of the medium. This law is also known as *Snell's law*.

### *i. Refractive Index*

Suppose a ray of light travels from a rarer medium 1 to a denser medium 2 then it is observed that the ratio of velocity of light in medium 1 to the velocity of light in medium 2 for a given pair of media is always constant. This constant ratio is called the refractive index of the second medium with respect to the first. It is represented as ${}_1\mu_2$ .

If $v_1$ is the velocity of light in medium 1, and $v_2$ is the velocity of light in medium 2, the refractive index of the second medium with respect to the first is written as

$${}_1\mu_2 = \frac{v_1}{v_2}$$

From Snell's law, the refractive index of the medium is also calculated by using the formula,

$${}_1\mu_2 = \frac{sin\ i}{sin\ r}$$

However, if the first medium is vacuum(or air), the refractive index of the other medium is simply denoted by Greek letter $\boldsymbol{\mu}$ (mu). It is called absolute refractive index of the medium.

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Refractive index of a medium depends upon the nature of material of the medium, wavelength or colour of the light used and the temperature. Therefore, the values of refractive index is different for different pairs of media. The refractive index of medium is found to decrease as the wavelength of the light increases. It is also found to decrease with increase in temperature. But, it is prominent only in the case of gases.

The absolute refractive indices of some common transparent substances are given in Table 5.1.

### Table 5.1

| Substances | Absolute refractive index (μ) |
| --- | --- |
| Water | 1.33 |
| Alcohol | 1.37 |
| Diamond | 2.41 |
| Ordinary glass | 1.53 |
| Crown glass | 1.53 - 1.61 |
| Flint glass | 1.62 - 1.71 |
| Ice | 1.31 |
| Rock salt | 1.56 |

**Example 5.1**

Light travels with a speed of $3 \times 10^8$ $ms^{-1}$ in air. Calculate its velocity in glass if the refractive index of glass is 1.5.

**Solution:**

$$v_a = 3 \times 10^8\ ms^{-1};\ {}_a\mu_g = 1.5\ ;\ v_g = ?$$

$${}_a\mu_g = \frac{v_a}{v_g}$$

$$1.5 = \frac{3 \times 10^8}{v_g}$$

$$v_g = \frac{3 \times 10^8}{1.5} = 2 \times 10^8\ ms^{-1}$$

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**Example 5.2**

A monochromatic ray of light falls on the surface of a transparent medium at an angle of incidence 40° in air and then it gets refracted through the medium making an angle of 28°to the normal. What is the refractive index of the transparent medium?

**Solution:**

$$i = 40^0; r = 28^0 ; \mu = ?$$

$$\mu = \frac{\sin i}{\sin r}$$

$$\mu = \frac{\sin 40^0}{\sin 28^0}$$

$$\mu = \frac{0.643}{0.469} = 1.37$$

## *ii. Principle of reversibility*

According to principle of reversibility, the path of light ray is reversible.

In Figure 5.3 given below, a ray of light AO is passing from a rarer medium 1 to denser medium 2. It is incident along the line AO and is refracted along the line OB. According to principle of reversibility, if the ray of light BO passes from a denser medium 2 to rarer medium 1, the ray refracts along the line OA.

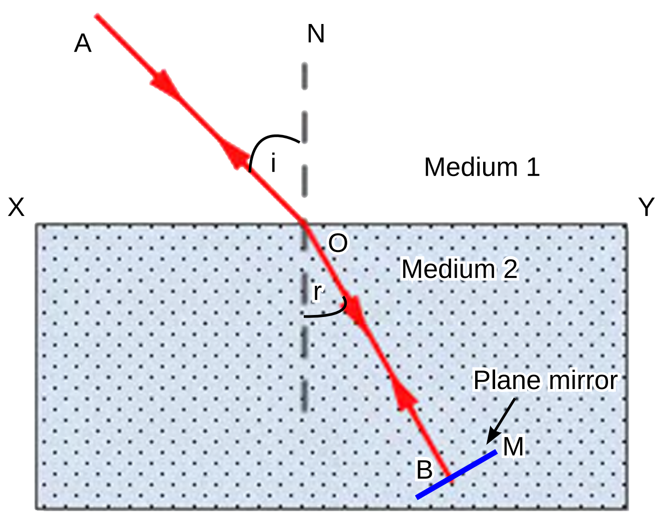


***Figure 5.3 Principle of reversibility***

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For the refraction of light from medium 1 to medium 2, the refractive index of medium 2 with respect to medium 1 is

$${}_1\mu_2 = \frac{\sin i}{\sin r} \quad \text{............. } \textit{equation (i)}$$

When the ray of light passes from the medium 2 to medium 1, the refractive index of the medium 1 with respect to medium 2 is

$${}_2\mu_1 = \frac{\sin r}{\sin i} \quad \text{............. } \textit{equation (ii)}$$

From equations (i) and (ii),

$${}_1\mu_2 \times {}_2\mu_1 = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i}$$

$$\text{or } {}_1\mu_2 \times {}_2\mu_1 = 1$$

$$\therefore {}_1\mu_2 = \frac{1}{{}_2\mu_1}$$

**Example 5.3**

The refractive index of rock salt with respect to water is 1.17. What will be the refractive index of water with respect to rock salt?

**Solution:**

*Refractive index of rock salt with respect to water,* ${}_w\mu_r = 1.17$

*Refractive index of water with respect to rock salt,* ${}_r\mu_w = ?$

$${}_r\mu_w = \frac{1}{{}_w\mu_r}$$

$${}_r\mu_w = \frac{1}{1.17} = 0.85$$

## Activity 5.2 To determine the refractive index of a glass slab

Materials required: Glass slab, six pins, sheet of white paper, drawing board, protractor and pencil.

### Procedure

**Step 1** ☞ Place a glass slab on a white sheet of paper fixed on a drawing board. Draw its outline PQRS carefully with a pencil.

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**Step 2** Remove the slab and draw a normal (perpendicular) NN', on one of the longer sides of its outline.

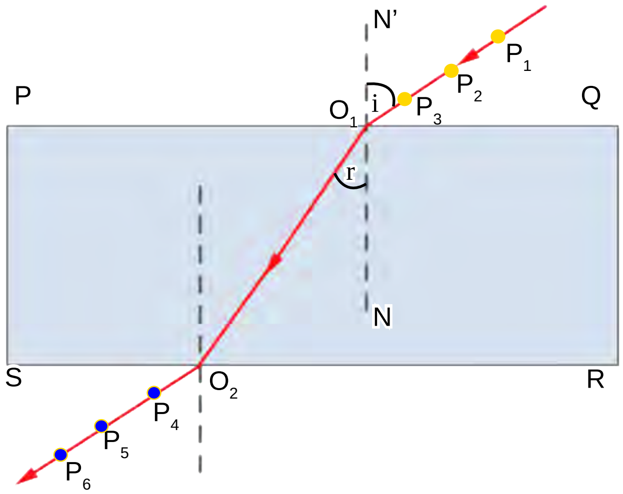


***Figure 5.4***

**Step 3** With the help of a protractor, draw angles of incidence of 40˚,50˚,and 60˚ to the normal in the air as shown in Figure 5.4.

**Step 4** Fix three pins $P_1$, $P_2$ and $P_3$ on the incident ray, making an angle of incidence 40˚ with the normal.

**Step 5** Place the glass slab on its outline. Look through the other side of the slab, opposite to the incident ray, and place the other three pins $P_4$, $P_5$ and $P_6$ in straight line to the pins $P_1$, $P_2$ and $P_3$. They must be placed based on No Parallax method.

**Step 6** Remove the slab and join the three points $P_4$, $P_5$ and $P_6$ with a straight line. Extend the line to meet the outline PQRS at $O_2$.

**Step 7** Join $O_1$ to $O_2$ to represent the refracted ray for $\angle$ i = 40˚. Then measure the angle of refraction, $\angle$ r between the refracted ray and the normal. Record it in Table 5.2.

**Step 8** Repeat Step 4 to Step 7, for angles of incidence of 50˚and 60˚.

**Step 9** Calculate the sine of angles of incidence and the sine of angles of refraction with the help of a calculator,and record them in the Table 5.2. Then calculate the refractive index for each set, and find the average of all the three sets of readings.

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Table 5.2

| Angle of incidence (i) | Angle of refraction (r) | Sine i | Sine r | μ=sin i/sin r | Mean μ |
|---|---|---|---|---|---|
| 40˚ | | | | | |
| 50˚ | | | | | |
| 60˚ | | | | | |

**Now answer the following questions:**

1. What happens to the angle of refraction when the angle of incidence increases?
2. How do the change in the values of $\angle$ i and $\angle$ r affect the refractive index? What can you conclude?
3. What conclusion can you draw from the ratios of *sin i* to *sin r* in all the three sets of readings? What could be the reason for this?

### *iii. Real and apparent depth*

When a glass slab is placed over some printed paper, the print appears to be raised when viewed through the slab. This is due to the refraction of light through the glass slab. As shown in Figure 5.5 , the rays of light coming from the bottom of the slab O bend away from the normal when they pass from glass to air. These rays appear to come from O′ to us since our eyes follow a straight path. Therefore, the print at the bottom of the slab appears to be raised.

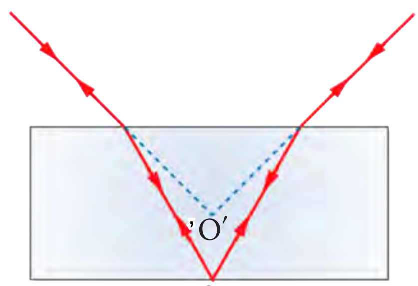

**Figure 5.5**

The distance of O from the upper face of the slab is called the real depth, and the distance of O′ from the upper face of the slab is called the apparent depth. The ratio of real depth to apparent depth is also found to be equal to the refractive index of the material of the slab.

**Example 5.4**

Kamala observed that the depth of a swimming pool appears to be 72 cm when viewed from the top. What is the real depth of the swimming pool? The refractive index of water is $\frac{4}{3}$.

**Solution:**

$$\text{Apparent depth} = 72\ cm\ ;\ \text{Refractive index} = \frac{4}{3}\ ;\ \text{Real depth} = ?$$

$$\text{Refractive index, } \mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

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$$\frac{4}{3} = \frac{Real\ depth}{72}$$

$$Real\ Depth = \frac{4 \times 72}{3} = 96\ cm$$

## Activity 5.3 Determining refractive index of a glass slab

Materials required: Glass slab, six pins, drawing board, white sheet of paper and pencil.

### Procedure:

**Step 1** Place a glass slab on a white sheet of paper fixed on a drawing board. Draw its outline PQRS carefully with a pencil.

**Step 2** Remove the slab and draw a normal (perpendicular) NN', on one of the longer sides of its outline. Draw an incident ray inclined as shown in Figure 5.6. Fix three pins $P_1$, $P_2$ and $P_3$ on the incident ray. Mark point O at the point of incidence.

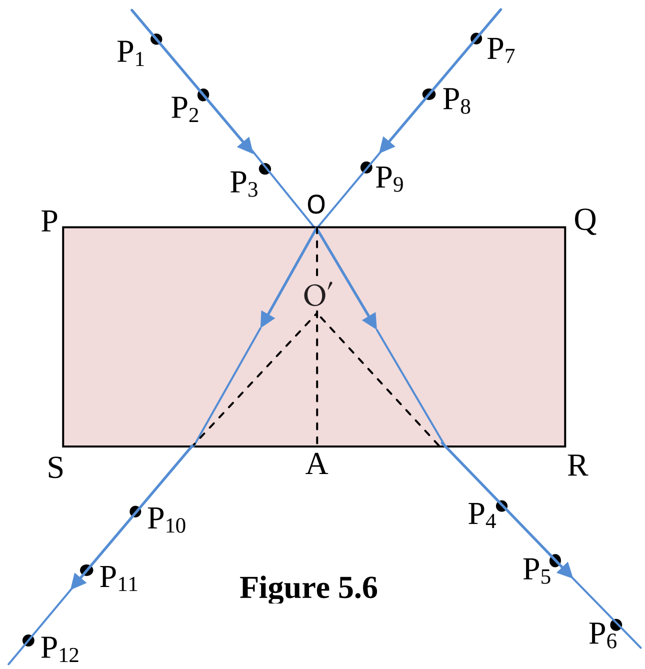


*Figure 5.6*

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**Step 3** ☞ Replace the slab in its outline. Look through the side of the slab opposite to that of the incident ray and fix three pins $P_4$, $P_5$ and $P_6$ in straight line to the incident ray.

**Step 4** ☞ Remove the slab and join the points $P_4$, $P_5$ and $P_6$ with a straight line.

**Step 5** ☞ Draw another incident ray on the same side and incident at the same point O as the first incident ray. But it should be inclined towards the right side. Fix three pins $P_7$, $P_8$ and $P_9$ on this incident ray.

**Step 6** ☞ Repeat steps 3 and 4 to get the second emergent ray.

**Step 7** ☞ Remove the slab and extend the two emergent rays towards the incident rays. Mark point O/ at the point of intersection of the two emergent rays.

**Step 8** ☞ Measure the perpendicular distance AO (real depth) and AO' (apparent depth). Calculate the refractive index of the glass slab.

## D. Dispersion of light

When there is sunshine after rain, sometimes we observe coloured arcs being formed in the air. These coloured arcs are called *rainbows*. Similarly, in the laboratory, rainbow colours can be produced by passing white light through a glass prism as shown in Figure 5.7. This phenomenon of splitting of white light into its constituent colours is called *dispersion of light*.

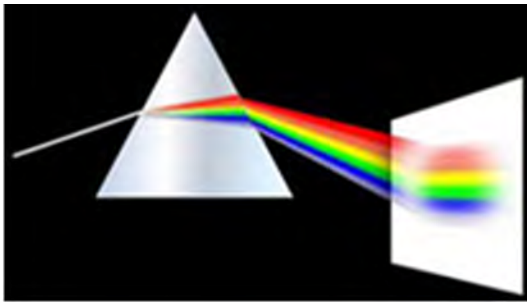

*Figure 5.7 Dispersion of light*

This phenomenon of dispersion of white light through a prism was first observed by Sir Isaac Newton. He confirmed that white light is composed of seven 'VIBGYOR' colours. They are violet, indigo, blue, green, yellow, orange and red. This arrangement of seven colours in the increasing order of wavelength is called *visible spectrum*. The seven VIBGYOR colours cannot be seen distinctly in the spectrum because of the overlapping of colours.

**Table 5.3**

| Colour of Light | Wavelength range (in metres) |
|---|---|
| Red | $6.2\times10^{-7}$ - $7.8\times10^{-7}$ |
| Orange | $5.9\times10^{-7}$ - $6.2\times10^{-7}$ |

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| | |
|---|---|
| Yellow | $5.8\times10^{-7}$ - $5.9\times10^{-7}$ |
| Green | $5.0\times10^{-7}$ - $5.8\times10^{-7}$ |
| Blue | $4.6\times10^{-7}$ - $5.0\times10^{-7}$ |
| Indigo | $4.4\times10^{-7}$ - $4.6\times10^{-7}$ |
| Violet | $3.8\times10^{-7}$ - $4.4\times10^{-7}$ |

When light travels from air to a transparent material medium like water or glass, it slows down and its wavelength changes. There is a change in the velocity and wavelength of light but frequency of light does not change. The velocity of light in vacuum (or air) is given by

$$c = frequency(f) \times wavelength\ in\ air\ (\lambda_0)$$

Therefore, the wavelength in air is given by

$$\lambda_0 = \frac{c}{f}$$

Similarly, the wavelength of light in medium other than air is given by

$\lambda = \frac{v}{f}$, where $\boldsymbol{v}$ is the reduced velocity of light and f is the frequency of light in that medium.

The ratio of wavelength of light in air to wavelength of light in that medium is

$$\frac{\lambda_0}{\lambda} = \frac{c}{v} = \mu$$

This relation also tells us that the refractive index of medium for different colours of light varies inversely to its wavelength in that medium. This means the refractive index of medium for light of longer wavelength is less than the refractive index of the same medium for light of shorter wavelength.

## E. Total internal reflection

When light passes from an optically denser medium to an optically rarer medium, the refracted ray bends away from the normal. Suppose XY is the surface of separation between air and water, and the source of light S is kept in denser medium as shown in Figure 5.8. When a ray of light AB passes from the denser medium to rarer medium, a part of it gets reflected in the denser medium along BC, and most of it gets refracted into the rarer medium along BD.

As the angle of incidence in the denser medium increases, the angle of refraction in the rarer medium also increases, as in the case of Ray 2 in Figure 5.8. But for a

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certain value of angle of incidence, the value of angle of refraction is equal to 90˚, as for Ray 3 in the figure. At this position, the refracted ray lies on the surface of separation making the angle of refraction maximum. This angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90˚ is called *critical angle* (***c***). If the angle of incidence increases beyond the critical angle, there is no further increase in the value of angle of refraction. In such a situation, the light is totally reflected into the denser medium, and hence, there is no refracted light in the rarer medium as in the case of Ray 4 in the figure. This phenomenon of light is called *total internal reflection*.

Total internal reflection of light is the phenomenon in which, a ray of light travelling from a denser medium to rarer medium is reflected back into the denser medium, provided the angle of incidence in the denser medium is greater than the critical angle for the given pair of media.

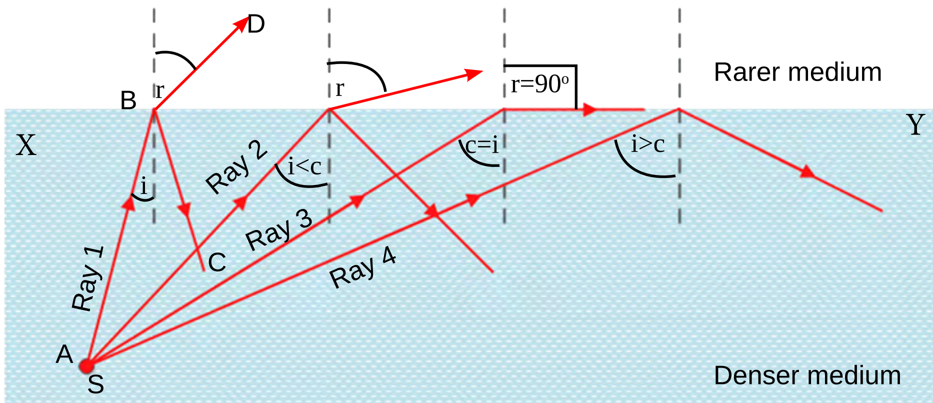


**Figure 5.8**

The necessary conditions for total internal reflection are as follows:

1. Light must pass from optically denser medium to optically rarer medium.
2. The angle of incidence in the denser medium must be greater than the critical angle for the given pair of media.

### i. Natural phenomena due to total internal reflection

**a. Mirage**

A *mirage* is an optical phenomenon which produces displaced image of far away objects. There are two types of mirage: inferior mirage and superior mirage.

While travelling in very hot places, we often see an image of approaching vehicle or an object on a pool of water on roads at a distance away from us. But as we approach that place, the water and the image disappear. This phenomenon is called inferior mirage. It is caused when cool layers of air lie above the warm layer of air. The illusion of pool of water is actually a virtual image of the sky below the road.

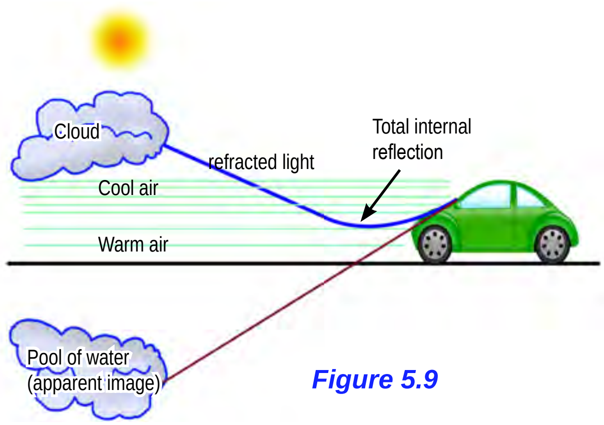


Figure 5.9

During daytime in hot deserts, travellers often see a pool of water beneath palm trees at some distance away from them. But when they reach that place, they do not find any water there. This illusion of pool of water beneath the palm trees is called inferior mirage. It is due to the phenomenon of total internal reflection of light.

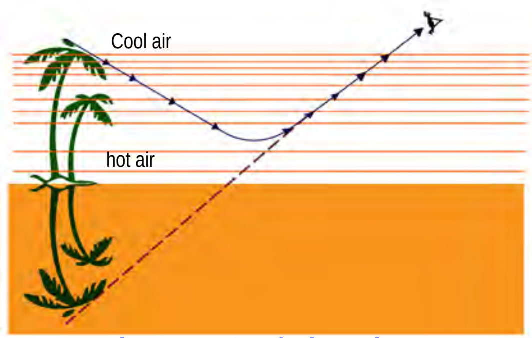


Figure 5.10 Inferior mirage

In deserts, the layers of air close to the ground are hot and thinner than the layers of air above. So the rays of light coming from the top of palm tree bend away from the normal as they pass from denser air to the rarer air below it as shown in Figure 5.10. This process continues till the angle of incidence is equal to the critical angle, c. Now when the angle of incidence exceeds the critical angle, light is totally reflected and it starts bending towards the normal as it passes from the rarer air to the denser air above it. So, to the eyes of the traveller, the ray appears to come straight from beneath the trees. As the density of air keeps on changing due to change in temperature, it gives an illusion of moving water below the trees.

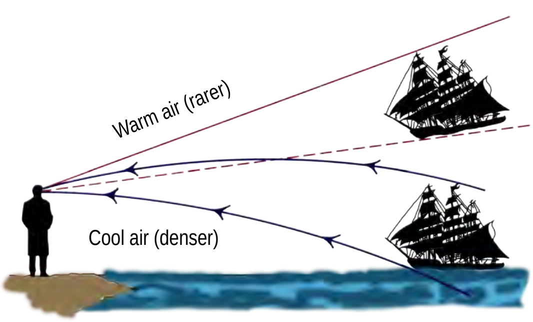


Figure 5.11 Superior mirage

Similarly, in very cold places, we often see images of objects in the air. This is called superior mirage. In this case, the layers of air near the ground are colder and denser than the air above them. The rays of light coming from objects on the ground travel from denser to rarer medium, bend away from the normal. Hence, we observe the superior mirages, and they can be inverted or upright. See Figure 5.11.

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**b. Sparkling of diamond**

The critical angle of diamond is only about 24˚. It is quite less compared to glass, whose critical angle is about 42˚. It is due to this reason that the total internal reflection of light takes place easily in diamonds. Further, the diamonds are cut in such a way that a ray of light entering the crystal is incident at a face at an angle greater than the critical angle, and suffers a total internal reflection. In this way, the ray suffers multiple total internal reflections at various faces. There are few faces available, where the angle of incidence is less than the critical angle, and the rays come out through those faces. Once the light enters the diamond, it suffers multiple total internal reflections and gets trapped inside the diamond for some time and eventually comes out.

***Figure 5.12 Sparkling of diamond.***

## *ii. Applications of Total internal reflection*

**(i) Optical fibre**

Optical fibres are very thin and long strands of glass or plastic, which are used to transmit signals in the form of light from one place to another with negligible loss of energy. It works on the principle of total internal reflection.

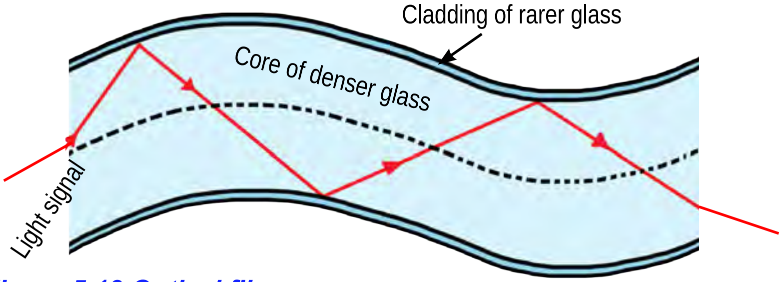


***Figure 5.13 Optical fibre***

Optical fibre consists of glass of high refractive index, coated with glass of lower refractive index. The inner part is called the core, and the outer coating is called cladding.

When light enters from one end of the optical fibre, light gets refracted into the core of the optical fibre. It is incident at the boundary of the two materials at an angle greater than the critical angle of the material of the fibre. The total internal reflection of light takes place. The light is again incident at the other boundary at an angle greater than the critical angle. Hence, the light suffers a series of total internal

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reflections inside the fibre, and finally emerges out from the other end.

Optical fibres are used to carry telephone, television and computer signals as pulses of light from one place to another. They are also used to see ulcers and other foreign objects inside our internal organs in endoscopy.

**(ii) Periscope**

Periscope is a device used to view objects, which are above our eye level. It is used to watch matches over the heads of the crowd in stadium. Soldiers use periscopes to watch the movements of their enemies from a trench.

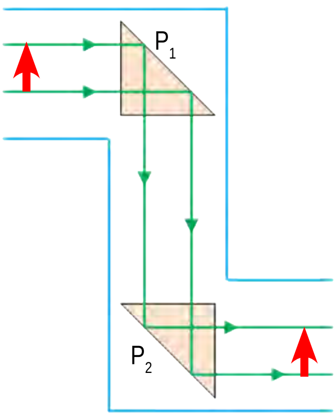

*Figure 5.14 Periscope*

A periscope consists of two right angled isosceles prisms, fitted in a tube as shown in the Figure 5.14. A ray of light from a distant object is incident on the hypotenuse face of the prism $P_1$, and is totally reflected to the hypotenuse face of the other prism $P_2$. Finally, the ray of light is totally reflected into the eyes of the observer. The image seen is bright as compared to the periscopes made of plane mirrors.

## Questions

1. Tshering passes laser light from air to glass and is incident on a glass surface at an angle of 30°. At what angle will it get refracted inside the glass? Take absolute refractive index of glass as 1.5.
2. Draw a diagram of a periscope that is constructed using plane mirrors.
3. A ray of blue light and a ray of orange light are passing through water in a beaker. Which light reaches the bottom of the beaker first? Which light do you think will have higher refractive index?

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## Summary


- The phenomenon of bending of light ray, when it travels from one medium to another medium is called refraction of light.
- The refractive index of the medium may be defined as the constant ratio between the sine of angle of incidence to the sine of angle of refraction for a given pair of media.
- The phenomenon of splitting of white light into its constituent colours is called dispersion of light.
- Since the velocity of different colours of light are different in material media, the value of refractive index of the medium for different colours of light, differs slightly from each other.
- The angle of incidence in the denser medium, for which the angle of refraction in the rarer medium is 90˚ is called critical angle.
- The phenomenon of reflecting light into the denser medium, when the ray of light is travelling from denser to rarer medium, provided the angle of incidence is greater than the critical angle for the given pair of media is called total internal reflection.
- A mirage is an optical phenomenon due to which, an image of far away object appears to be displaced up or down, or to one side of it. There are two types of mirage namely, inferior mirage and superior mirage.
- Total internal reflection is used in optical fibres to transmit signals from one place to another.
- Optical fibres are used in telecommunications and endoscopy.


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## Exercises

***I. Fill in the blanks.***

1. The refractive index of a medium is the ratio of the velocity of light in ____________ to the velocity of light in _____________.
2. The incident ray and the emergent ray are ____________ to each other in the refraction of light through a glass slab.
3. People observe inverted trees above the calm lake. This illusion is called ________________.
4. Total internal reflection occurs, when a ray of light passes from ___________ medium to ___________ medium.
5. The apparent distance of the object will be greater, when the observer is in the ________ medium.

***II. Match the items of Column A with correct answers of Column B.***

| Column A | Column B |
|---|---|
| 1.Dispersion | a. Total internal reflection |
| 2. Critical angle | b. Refraction of light |
| 3. Optical fibre | c. spectrum |
| 4. Principle of reversibility | d. ${}_1\mu_2 = \frac{\sin i}{\sin r}$ |
| 5. Snell's law | e. ${}_2\mu_1 = \frac{1}{{}_1\mu_2}$ |
| | f. $\mu = \frac{c}{v}$ |
| | g. $\angle r = 90^0$ |

***III. Check whether the following statements are True or False. Correct the false statements.***

1. The cause of refraction of light is due to the change in the intensity of light in different media.
2. Total internal reflection takes place only when light ray travels from denser to rarer medium.
3. The refractive index of a material is dependent on the colour of light .
4. The dispersion of light is due to the difference in the velocity of different colours of light in air.
5. Diamond sparkles due to the phenomenon of reflection of light.

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***IV. Multiple Choice Questions.***

1. When a ray of light is incident normally on a plane surface of a glass block, the refracted ray

   A returns to the first medium.

   B bends away from the normal.

   C bends towards the normal.

   D does not bend at all.

2. The refractive index of vacuum is

   A 0

   B 1

   C 1.5

   D 2

3. A ray of light is incident on the surface of water at 45°, and it gets refracted inside water at an angle of 32°. The absolute refractive index of water is

   A 1.6

   B 1.5

   C 1.33

   D 1

4. When a ray of light is incident at a critical angle in denser medium, the angle of refraction in rarer medium is

   A 0°

   B 45°

   C 90°

   D 180°

5. The refractive index of a medium depends upon

   A the temperature, colour of light and frequency of light.

   B colour of light, material of the medium and temperature.

   C the material of the medium, colour of light and intensity of light.

   D the velocity of light, material of the medium and frequency of light.

6. The critical angle for glass in air is $42^0$. Therefore, for total internal reflection to take place the

   A angle of incidence should be greater than $42^0$.

   B angle of incidence should be less than $42^0$.

   C angle of incidence should be equal to $42^0$.

   D light must travel from air to glass.

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7. When sunlight passes through droplets of water suspended in the air, it splits up into seven colours forming rainbow. This phenomenon of splitting of light is due to the change in the
   A intensity of light.
   B wavelength of light.
   C frequency of light.
   D temperature of light.
8. We cannot see the seven VIBGYOR colours in the spectrum of white light distinctly, because of
   A reflection of light.
   B refraction of light.
   C overlapping of different colours of light.
   D white light consists of seven different colours.
9. When a ray of light passes from one medium to another medium, the property of light that does not change is
   A speed.
   B intensity.
   C frequency.
   D wavelength.
10. The evening red sunset scene is a common observation in Southern Bhutan. Many people enjoy watching this phenomenon. This phenomenon is well explained by
   A refraction of light in the air.
   B reflection of light in the air.
   C different coloured light has different velocity.
   D different coloured light are refracted through the air.

V. *Answer the following questions.*

1. Green light has higher refractive index than orange light for the same material medium. Explain.
2. Design an experimental set-up to show that white light is made up of different colours of light.
3. Explain refractive index in your own words.
4. The wavelength of green light in vacuum is $504 \times 10^{-9}$ m . What will be its new wavelength when it travels through water? Take refractive index of water as 1.33.

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5. A red ray and a blue ray are refracted from rarer medium to a denser medium at the same angle of incidence as shown in Figure 5.15. In which case will the angle of refraction be greater? Why?

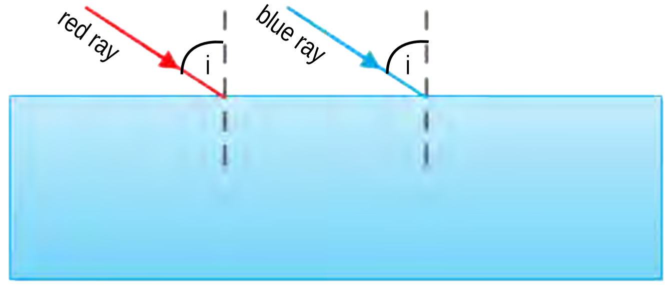


*Figure 5.15*

6. State the principle of reversibility of light.
7. A ray of light passes through a glass slab as shown in Figure 5.16. The incident ray is on plane WXYZ, normal MN and refracted ray are on plane PQRS and the emergent ray is on plane ABCD.

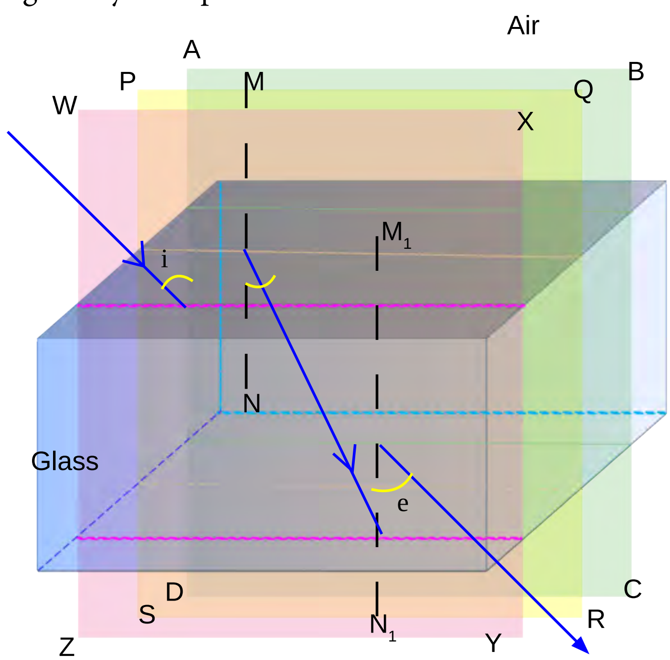


*Figure 5.16*

(i) State the law of refraction defied in the Figure 5.16.

(ii) Redraw the diagram to trace the correct path travelled by the ray of light.

(iii) Define plane.

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8. The velocity of light changes from $3\times10^8$ $ms^{-1}$ to $2\times10^8$ $ms^{-1}$ when it travels from air to glycerine. Calculate the refractive index of the glycerine.
9. Karma wanted to observe the phenomenon of total internal reflection. What necessary conditions are needed to be fulfilled by him?
10. Compare total internal reflection and reflection of light by a mirror.
11. Punam had a severe stomach ache. When she visited the hospital, doctor advised her for endoscopy. How is optical fibre used in endoscopy?
12. Passang had a piece of glass and a diamond of same shape, size and colour. When he kept them in the sun, he found that the diamond sparkled more brilliantly than the glass piece. What could be the reason for this difference?
13. With the help of a ray diagram, explain why does a river bed appear shallower than it actually is?
14. The phenomenon of total internal reflection does not take place, when the light travels from rarer medium to denser medium. What could be the reason for this?
15. In hot summer days, road looks wet at certain distance ahead, although there is no water there. Why?

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6

# WAVES

If a stone is thrown into a still water, ripples travel outward in the form of concentric circles from the point of disturbance. These ripples are the disturbances in the water, which make the particles of the water move up and down alternately. Such periodic disturbances in a medium are called waves. Waves are actually energy. It is the energy, not water, which moves across the surface of water as waves. Water particles have little movement as the wave passes by. Sound and light also propagate through a medium or space in the form of disturbances from their source. Such waves are called light waves and sound waves.

This chapter deals with different types of waves, their properties and applications.

## 1. Characteristics of Waves

### Learning Objectives

On completion of this topic, you should be able to:

- describe the properties of waves.
- demonstrate properties of longitudinal waves, using string or spring.
- define the terms time period, frequency, wavelength and amplitude of a wave.
- measure time period of a simple pendulum.
- solve problems using the equation, $v = f\lambda$ .
- explain that waves transfer energy without transferring matter.
- describe uses of ultrasound e.g. medical scanning, SONAR (measuring depth of ocean, human and bats)and radio waves in RADAR.

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## A. Types of waves

The winds cause waves on the surface of the lakes. The wind transfers some of its energy to the water, through friction between the air molecules and the water molecules. Stronger wind causes larger waves. You can make your own miniature waves by blowing across the surface of a pan of water.

**Figure 6.1 Ripples on water**

Waves of water do not move horizontally, they only move up and down (a wave does not represent a flow of water). You can see a demonstration of this by watching a floating paper boat move up and down with a wave. The boat moves horizontally with the wave only.

Tsunamis, sometimes called tidal waves, are different from surface waves as they are usually caused by underwater earthquakes, volcanic eruptions, or landslides.

Waves are classified into two types. They are *mechanical waves* and *electromagnetic waves*.

Mechanical waves are waves which require material medium for their transmission. Sound waves, water waves, vibrations produced in a stretched string, etc. are some examples of mechanical waves.

Electromagnetic waves are waves, which do not require any material medium for their transmission. These waves can also travel through vacuum. Examples of electromagnetic waves are light waves, radio waves, gamma rays, ultraviolet rays, infrared radiations, etc.

Mechanical waves can be transverse, as well as longitudinal, but electromagnetic waves are always transverse.

### i. Transverse waves

Transverse waves are waves in which the particles vibrate perpendicular to the direction of propagation of waves like the waves on the surface of the water. It consists of crests and troughs. The crest is the maximum upward displacement of the particle from its rest position or mean position. The trough is the maximum downward displacement of the particle from its

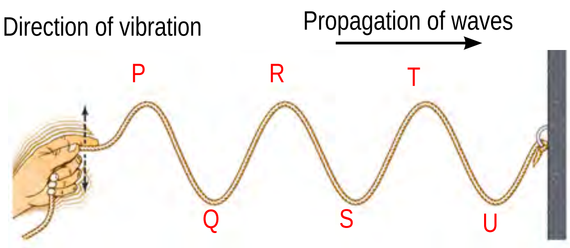


**Figure 6.2 Transverse Waves**

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rest position (mean position). In Figure 6.2, crests are indicated by P, R and T and troughs are Q, S and U. Electromagnetic waves are always transverse in nature. Light waves, radio waves, microwaves, ultra-violet rays, infra-red rays, X-rays and gamma rays are electromagnetic waves.

### *ii. Longitudinal waves*

Longitudinal waves are waves in which the particles vibrate along the direction of propagation of waves. Sound waves are longitudinal in nature. It consists of compressions and rarefactions. Compression is the region, where the layers of medium come closer to each other. High density and high pressure is created at such points. Rarefaction is the region, where the layers of the medium are far away from each other. Low density and low pressure is created at such regions. Point B is a compression, and points A and C are rarefactions in Figure 6.3.

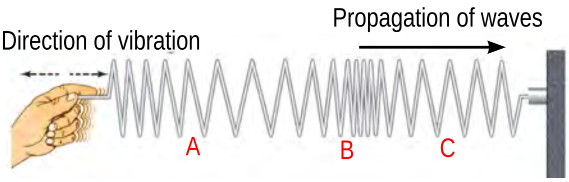

*Figure 6.3 Longitudinal Waves*

## Activity 6.1 Demonstrating the longitudinal waves

Materials required: Slinky spring, a small piece of ribbon.

**Procedure:**

**Step 1** ☞ Take a slinky spring and hold at one end.

**Step 2** ☞ Now pull the spring from the free end and flick it back and forth in the direction of the spring several times. Observe what happens.

**Step 3** ☞ Tie a ribbon in the middle of the spring and repeat step 2. Observe the movement of the ribbon.

**Answer the following questions:**

1. What do you observe in the direction of movement of the ribbon in step 3? What does the ribbon indicate here?
2. State some properties of longitudinal wave from the above activity?
3. How would you produce transverse wave using the same spring?

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The sound waves travel through a medium in the similar manner like the disturbance in the slinky spring. The places where the spring comes closer are called compressions, and the places where the spring moves far away from each other are called rarefactions. Similarly, sound waves also travel through different media forming compressions and rarefactions.

The propagation of sound waves in air is shown in figure 6.4. The sound waves are produced by a vibrating tuning fork. The Figure 6.4(a) shows a tuning fork with two prongs A and B at rest.

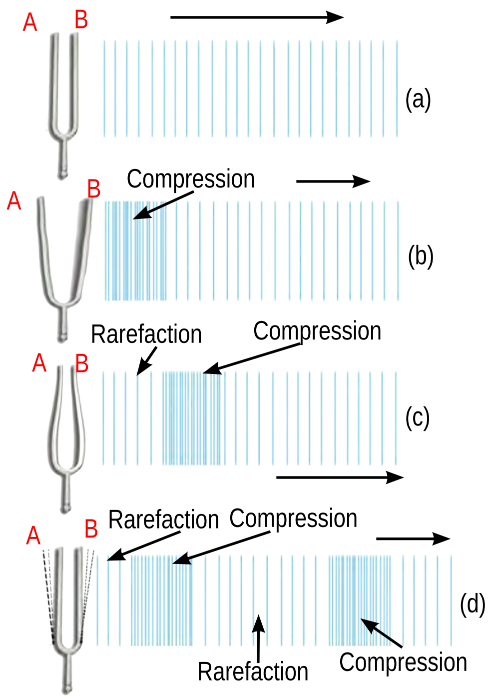


*Figure 6.4 Sound waves*

When the tuning fork is set into vibrations, the prong B of the tuning fork moves towards the right as shown in Figure 6.4(b). In this position of the tuning fork, the layers of medium on the right side of the tuning fork are compressed, and hence, compression is formed just close to the prong B. When the prong moves towards left, the layers of medium on the right become rarefied, and the compression which was initially formed, moves forward towards the right as shown in figure 6.4(c). In this manner, when the prongs of the tuning fork move back and forth during vibration, the compressions and rarefactions are formed alternately and they move forward in the air. The combination of alternate rarefactions and compressions in a quick interval of time produce a sound wave that is a longitudinal wave.

## B. Terms used to describe waves

Waves can be described with the help of the following basic properties:

- **Wavelength**: In transverse waves, it is the distance between two consecutive crests or two consecutive troughs and in longitudinal waves; it is the distance between two consecutive compressions or two consecutive rarefactions. It is denoted by Greek letter λ (lambda). It is measured in metres (m) or centimetres (cm). Smaller units of wavelength are angstrom (Å) and nanometre (nm).

  1 Å = $10^{-10}$ m

  1 nm = $10^{-9}$ m

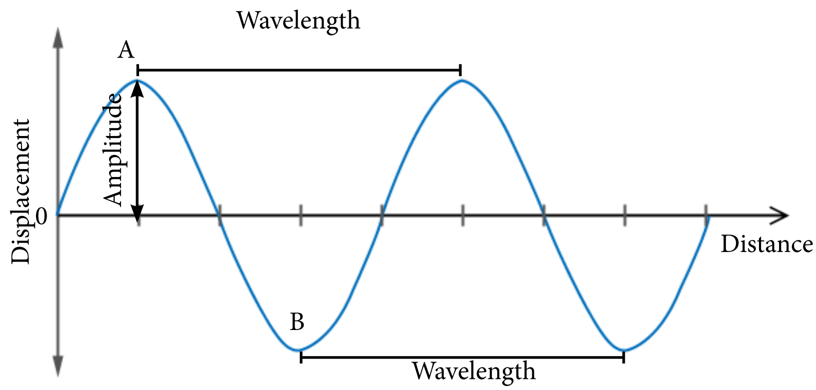


*Figure 6.5*

- **Frequency**: It is the number of waves passing through a point in one second. It is denoted by letter f. It is measured in hertz (Hz) or cycles per second (cps).
- **Amplitude**: It is the maximum displacement of the particle in either positive direction or negative direction. It is denoted by letter a. It is measured in metres (m) or centimetres (cm). Its smaller units are angstrom (Å) and nanometre (nm).
- **Time period**: It is the time taken by one wave to pass through a point. It is denoted by letter T. It is measured in seconds(s).
- **Wave Velocity**: It is the distance travelled by the wave in one second in the direction of its propagation. It is measured in metre per second (m/s) or centimetre per second (cm/s).

## Activity 6.2 Measuring time period of a simple pendulum

Materials required: a metallic bob with hook, cotton thread of about 1 m, two split pieces of cork, clamp stand and stop watch.

### Procedure

**Step 1** ☞ Tie the bob to one end of the cotton thread and pass the other end through the split pieces of cork. Fix the cork pieces firmly in the clamp as shown in Figure 6.6.

**Step 2** ☞ Adjust the height of the clamp so that the bob hangs about 2-3 cm above the surface of the table.

**Step 3** ☞ Draw two lines with a chalk on the table just below the bob, one line parallel to the edge of the table and the other line perpendicular to it. Mark the points A and B on either sides of the point of intersection of the two lines as shown in Figure 6.6.

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**Step 4** ☞ Now take the bob about 2 cm to one side say A and release it. It should start oscillating along the line AB.

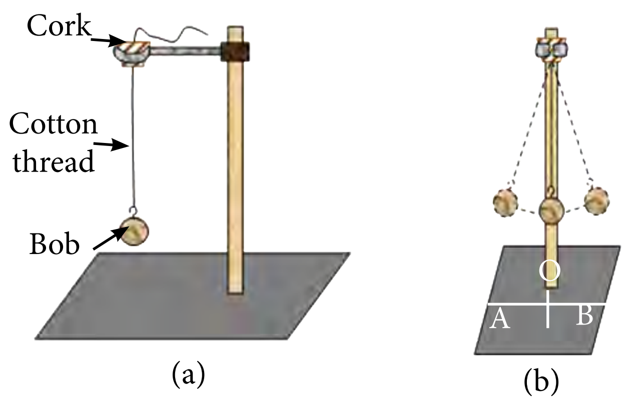


*Figure 6.6*

**Step 5** ☞ As the bob crosses the point of intersection of the two lines, start your count from 0 and start the stop watch at the same time. When the bob returns to the midpoint or mean after reaching both the ends A and B count 1. This is one oscillation. Continue your count till 20 oscillations and stop your stop watch. Now record the time (t) in the Table 5.1 given below.

**Step 6** ☞ Repeat Step 4 and Step 5 two more times.

**Table 5.1**

| Serial number | Time taken for 20 oscillations (t) | Time period (T) | Mean time period |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

**Answer the following questions:**

1. How did you calculate the time period in the third column?
2. Why is the time period not recorded directly during the experiment?
3. Explain time period based on the mean time period calculated in the above experiment.
4. What is the purpose of the lines that you have drawn?
5. Why is it important to calculate time period in this activity?

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### i. Relation between time period and frequency

If $f$ is the frequency of the waves then,time taken for $f$ vibrations = 1 second

Time taken for 1 vibration, $T = \frac{1}{f}$

$$\therefore T = \frac{1}{f}$$

$$or,\ f = \frac{1}{T}$$

### ii. Relation between wave velocity, frequency and wavelength

The distance covered by the wave in one second is equal to its wavelength, λ. Therefore,

$$Wave\ velocity\ (v) = \frac{Wavelength\,(\lambda)}{Time\ period\,(T)}$$

$$Or,\ Wave\ velocity\ (v) = frequency\,(f) \times Wavelength\,(\lambda)$$

**Example 6.1**

Rinchen plays a guitar and produces a transverse wave of frequency 10 Hz. Find its time period.

**Solution:**

$f$=10 Hz

$T$=?

$$T = \frac{1}{f} = \frac{1}{10} = 0.1\ seconds$$

**Example 6.2**

Tshering heard a loud sound coming from a distant place. If sound waves travel in the air at a velocity of 340 m/s and the frequency of 1.1×10$^5$ Hz, what is its wavelength?

**Solution:**

$v$ = 340 m/s

$f = 1.1 \times 10^5$ Hz

$\lambda$ = ?

$v = f \times \lambda$

$$\lambda = \frac{v}{f} = \frac{340}{1.1 \times 10^5} = 3.09 \times 10^{-3}\ m$$

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**Example 6.3**

Light wave of wavelength 500 nm travels through a medium with a frequency of $3 \times 10^{14}$ Hz. What is its velocity through that medium?

**Solution:**

$$f = 3 \times 10^{14}\ Hz$$

$$\lambda = 500\ nm = 500 \times 10^{-9}\ m$$

$$= 5 \times 10^{-7}\ m$$

$$v = ?$$

$$v = f \times \lambda$$

$$v = 3 \times 10^{14} \times 5 \times 10^{-7}$$

$$v = 1.5 \times 10^{8}\ m/s$$

**Example 6.4**

A transverse wave passes through a medium as shown in Figure 6.7. Find its wavelength, amplitude and frequency if its velocity is 330 m/s.

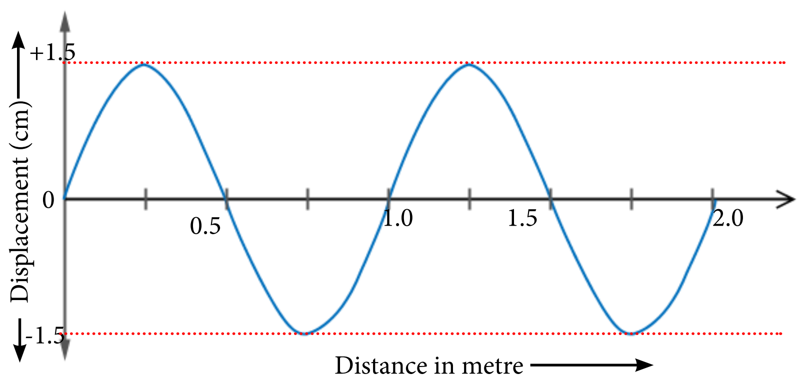


**Figure 6.7**

**Solution:**

$$a = 1.5\ cm$$

$$\lambda = 1.0\ m$$

$$v = 330\ m/s$$

$$f = v/\lambda$$

$$f = 330/1.0$$

$$f = 330\ Hz.$$

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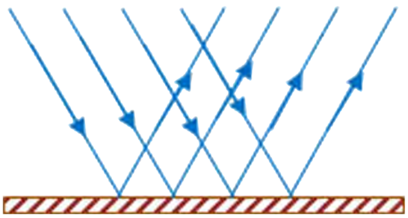
## C. Properties of waves

The different types of waves undergo phenomena like reflection, refraction, dispersion, interference, diffraction, polarisation, etc. Water waves are probably the most tangible type of wave. For this reason, water waves can be useful in studying wave properties in general.

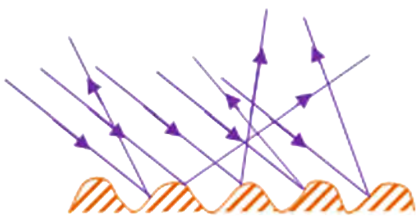
### *i. Reflection of Waves*

All kinds of waves are found to bounce back when they strike a reflecting surface. This phenomenon of bouncing back of waves when they fall on a rigid surface is called reflection of waves.

It is due to the reflection of light waves that we are able to see objects around us. If light falls on a smooth surface, regular reflection takes place, and if light falls on a rough surface then, irregular reflection of light takes place. This is an example of reflection of transverse waves.



(a) Regular reflection of light



(b) Irregular reflection of light

*Figure 6.8*

The sound waves also undergo the phenomenon of reflection. It is due to the reflection of sound waves that we are able to hear echo. Echo is the sound reflected from far off rigid surfaces like walls, cliff, buildings, etc. Unlike light waves, sound waves require large reflectors for reflection. This is because sound waves have longer wavelength compared to light waves. The wavelength of sound waves is nearly $10^7$ times the wavelength of light waves.

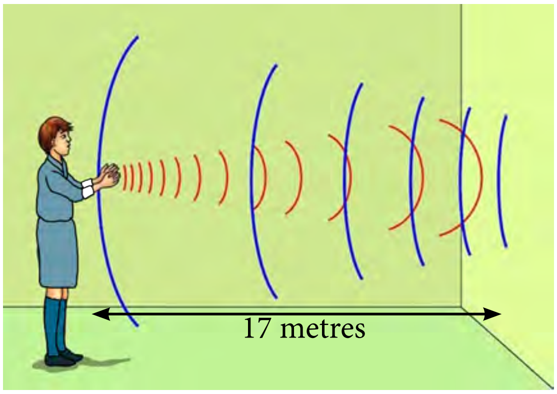



*Figure 6.9 Echo*

For the echo to be heard clearly, the minimum distance between the reflector and the source of sound should be at least 17 metres. This is because the persistence of hearing for human ear is about 0.1 seconds. This means that when we hear any sound, it persists in our ear for 0.1 seconds. Hence in order to hear echo distinctly, the distance between the source of sound and the obstacle must be equal to the half the distance covered by the sound in 0.1 seconds. Since the velocity of sound in air is about 340 m/s, the distance between the obstacle and the source of sound is

$$2d = v \times t$$

$$2d = 340 \times 0.1$$

$$2d = 34\ m$$

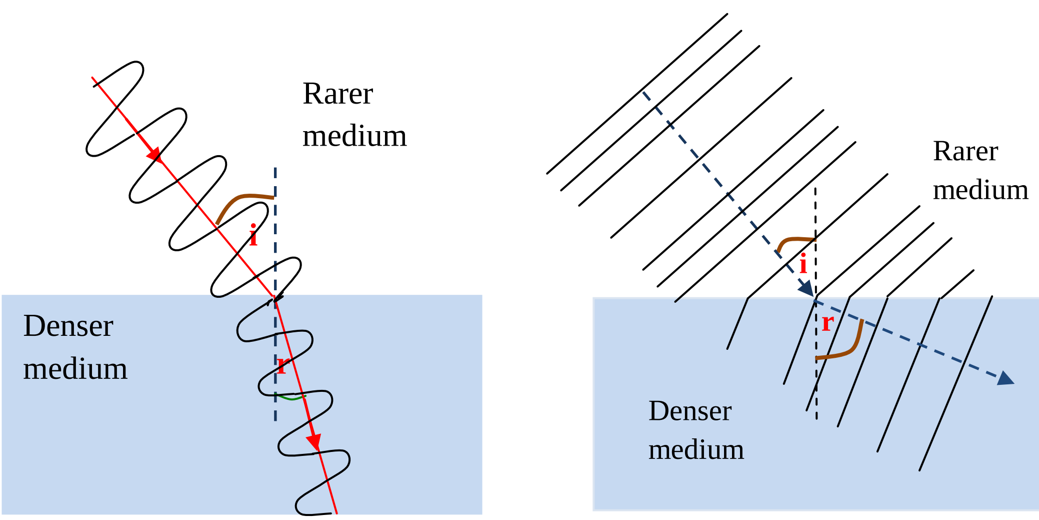
$$d = \frac{34}{2}\ m = 17\ m$$

### ii. Refraction of Waves

Both transverse wave and longitudinal wave change their velocity when they travel from one medium to another medium. Hence the bending of waves takes place when they enter different medium. This process of bending of waves when they change medium is called refraction of waves.

It is found that light waves travel faster in rarer medium and slower in denser medium. Its velocity in air or vacuum is $3\times10^8$ m/s which is its maximum velocity. The velocity of light in liquids is less than that in air but greater than that in solids.

Sound waves also change their velocity when they travel from one medium to another medium. But unlike light waves, sound waves travel faster in denser medium than in rarer medium. This means the velocity of sound is maximum in




(a) Refraction of light wave (b) Refraction of sound wave

**Figure 6.10**

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solids and minimum in air. The refraction of sound waves also obeys the same laws of refraction as that of light waves.

It is clearly shown in Figure 6.10 that when light wave travels from rarer to denser medium, the angle of incidence (i) is greater than the angle of refraction (r). But when sound wave travels from rarer to denser medium, the angle of incidence (i) is smaller than the angle of refraction (r). The refraction of sound wave is just opposite to that of light wave.

The refraction of sound waves takes place in the atmosphere due to change in the temperature. The velocity of sound waves increases with increase in temperature. It is due to this reason that we can hear distant sound more clearly at night than during daytime. During daytime, the air near the ground is warmer than the air which is at a greater height. The sound waves travel with less velocity in the cooler air high above the ground. So, the cooler air high above bends the sound waves away from the ground. At night, the air near the ground is cooler than the air at a height. The sound waves travel faster in the warmer air high above the ground. So, the warmer air at a height bends the sound waves downwards due to which we can hear the distant sound clearly at night.

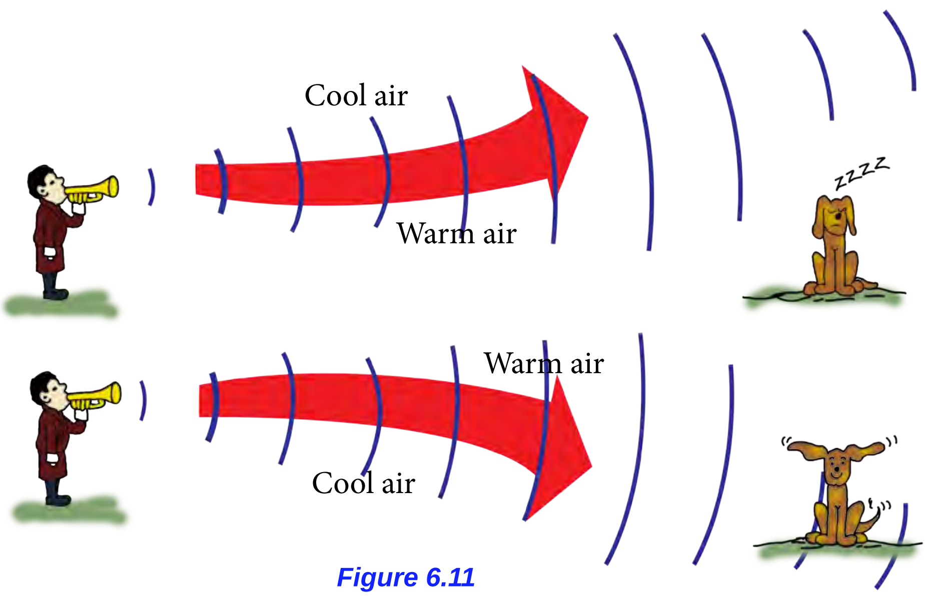


**Figure 6.11**

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## Questions

1 The time taken for 20 oscillations of a simple pendulum is 15 seconds. Calculate the number of oscillations made by the pendulum in one second.

2 The Bhutan Broadcasting Service radio broadcasts at $98\times 10^6$ Hz frequency. What is the wavelength of the radio wave? Take the velocity of light in air as $3\times10^8$ m/s.

3 Sonam wanted to produce echo in an open space. What are the two requirements that she needs to keep in mind?

## D. Transfer of Energy through Waves

If a stone is dropped into a pond, ripples move outward in concentric circles from the point of the disturbance. If a small piece of wood is placed over those ripples of water, the wood simply moves up and down, and does not move towards the side. This shows that when ripples travel over the surface of water, they only make the water particles move up and down about their mean positions, and do not move towards the sides of the pond. The water particles transfer energy from the point of disturbance to the sides of the pond in the form of ripples without transferring the matter. This confirms that the waves are the periodic disturbances in the medium, which transfer energy without the transfer of matter.

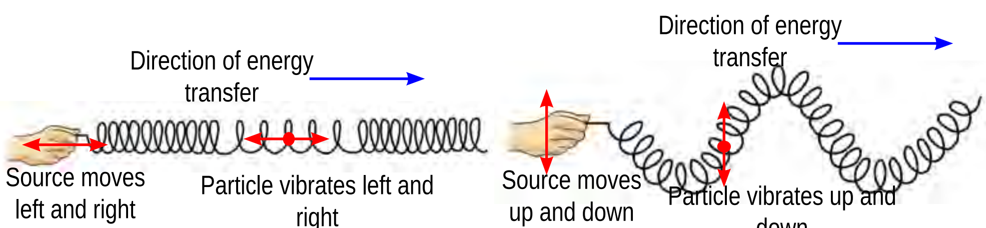


*Figure 6.12*

Similarly, when a slinky spring is given a jerk from one end, the vibrations travel towards the other end without transferring the particles of the spring. The vibrations simply make the particles of the spring to move up and down or sideways about their mean positions. The spring particles do not travel along with the vibrations.

This behaviour of waves of transferring energy without transferring matter is utilised for communication purposes in various fields.

## E. Uses of Waves

Sound waves of frequency greater than the upper limit of human's hearing range are called ultrasonic waves. Ultrasonic waves are used in different fields. They are used to

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detect objects and measure distances. Ultrasonic waves travel straight through long distances and can be confined into a narrow beam as they are not easily absorbed by the medium.

### i. Ultrasound

Ultrasound is used to image a foetus, tumours and internal organs in human's body. There are different types of media like fluids, tissues and bones in our body. The speed of ultrasonic waves differs in different medium. The ultrasonic pulses are reflected from the boundaries of different media and their images are seen on the screen of cathode-ray oscilloscope (CRO) . Looking at the images, the doctors can detect any kind of complications regarding the foetus, tumours and other internal organs in our bodies.

Figure 6.13 Ultrasound

### ii. SONAR

SONAR is an abbreviation for sound navigation and ranging. This method is used to measure the depth of sea and to detect the presence of objects.

In order to find the depth of the sea, the ultrasonic waves are sent to the bottom of the sea with the help of a hydrophone. The reflected wave is received by the receiver and the time taken by the waves for to and fro journey is recorded. If the speed of the sound in water is $v$ m/s and the time taken by the waves is t seconds, then the depth of the sea can be determined by using the formula $d = \frac{v \times t}{2}$.

Bats usually come out during night in search of their prey. At night, bat produces sound of very high frequency and sends this sound in all the directions. On hearing the reflected sound or echo from the obstacles, it can locate the position of those obstacles and prey. Hence, it can move freely at night without colliding with any obstacles.

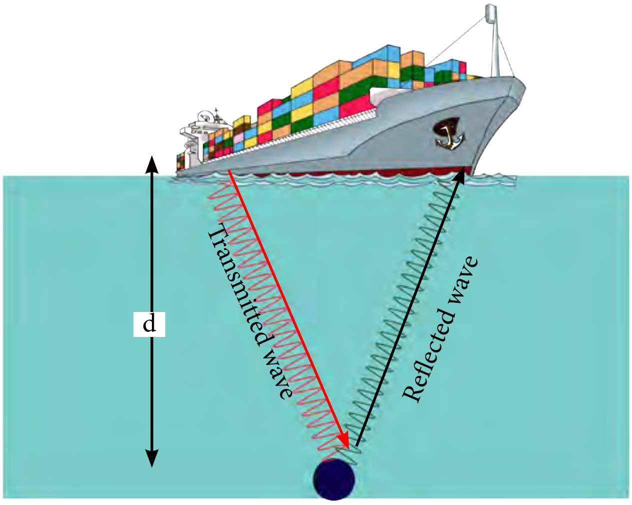


Figure 6.14 SONAR

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Similarly, fisherman also uses ultrasonic waves to locate the shoal of fishes inside the river.

### *iii. RADAR*

RADAR is an abbreviation for radio detection and ranging. This method is used to measure the distance of the moon from the Earth and to detect the presence of aircraft. RADAR is also used by policemen to check the speed of the vehicles from a distance.

This method is also similar to SONAR method. But the signals used in RADAR are radio waves or microwaves. Radio waves are electromagnetic waves, which travel with the same velocity as that of light. The radio signal is first sent to the moon or nearby aircraft and reflected. The reflected signal is received by the receiver and the time interval for the signal is noted. Knowing the speed of radio waves in air, the distance of the moon from the Earth is calculated by using the formula $d = \frac{v \times t}{2}$.

**Example 6.5**

Tobgay sends signal to the bottom of the sea from a ship on the surface of water and receives it back after 10 seconds. Calculate the depth of the sea, if the velocity of sound in water is 1450 m/s.

**Solution:**

$v = 1450\ m/s$

$t = 10\ s$

$$d = \frac{v \times t}{2} = \frac{1450 \times 10}{2} = 7250\ m$$

### Questions

1. Phuntsho hears the thunder 3 seconds after he sees lightning. How far from him has the lightning taken place? Take the velocity of light as 340 m/s.

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## Summary

- Waves are periodic disturbances in medium or space, which transfer energy without transporting the matter.
- There are two types of waves namely, mechanical waves and electromagnetic waves. Mechanical waves can be transverse as well as longitudinal, while electromagnetic waves are always transverse.
- Transverse waves are waves in which the particles vibrate perpendicular to the direction of propagation of waves.
- Longitudinal waves are waves in which the particles vibrate along the direction of propagation of waves.
- The phenomenon of bouncing back of waves when they fall on a rigid surface is called reflection of waves.
- The process of bending of waves when they change the medium is called refraction of waves.
- Waves can be measured based on their wavelength, amplitude, frequency, time period and wave velocity.
- Ultrasound is used to image a foetus, tumours and internal organs in human's body by reflection of these waves.
- SONAR is abbreviation for sound navigation and ranging. This method is used to detect the presence of objects by humans and bats, and to measure the depth of sea.
- RADAR is abbreviation for radio detection and ranging. This method is used to measure the distance of the moon from the Earth, and to detect the presence of aircraft.

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## Exercises

### *I. Fill in the blanks.*

1. If the particles of the medium are vibrating to and fro in the same direction of energy transfer, then the wave is a ________________ wave.
2. The distance between the two consecutive crests in a wave is called _________.
3. The light wave and sound wave refract in a ____________ manner when they pass from rarer medium to denser medium.
4. Zangmo plays a violin and produces a sound of frequency 100 Hz. Its time period is __________.
5. Ultra-violet rays can travel through vacuum. It is an example of__________.

### *II. Match the following.*

| Column A | Column B |
|---|---|
| 1. Depth of sea | a. Subsonic waves. |
| 2. Distance of moon from earth | b. Frequency. |
| 3. Compressions and rarefactions | c. Light waves. |
| 4. Crests and troughs | d. m/s. |
| 5. Number of waves per second | e. SONAR. |
| | f. wave velocity. |
| | g. RADAR. |

### *III. Check whether the following statements are True or False. Correct the false statements.*

1. Mechanical waves can travel through vacuum.
2. The vibrations are parallel to the direction of propagation in X-rays.
3. Time period is the time taken by a vibrating body to complete ten oscillations.
4. Sound waves travel faster through cooler air than warmer air.
5. There is variation of pressure and density of medium during propagation of transverse waves.

### *IV. Multiple Choice Questions.*

1. With increase in temperature, the velocity of the sound wave:

   A increases.
   B decreases.
   C remains same.
   D first increases and then decreases.

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2. Kuenga wants to talk to her friend through a long pipe filled with a medium. The best medium to fill the pipe for the best transmission of sound would be
   A air.
   B iron.
   C water.
   D hydrogen.
3. Lhaden produces a sound using a slinky spring as shown in Figure 6.15. The amplitude and wavelength of the sound are

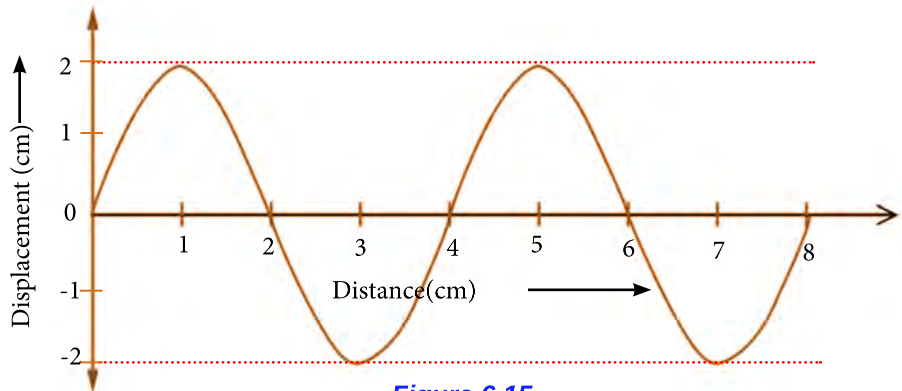


Figure 6.15

   A 1 cm and 1 cm respectively.
   B 2 cm and 2 cm respectively.
   C 1 cm and 2 cm respectively.
   D 2 cm and 4 cm respectively.
4. Astronauts cannot talk to each other through open space on the moon because sound waves
   A increase their speed on the surface of moon.
   B decrease their speed on the surface of moon.
   C require material medium for their propagation.
   D take longer time to travel on the surface of the moon.
5. In a coiled spring, the particles of the medium vibrate to and fro about their mean positions at an angle of
   A $0^\circ$ to the direction of propagation of wave.
   B $45^\circ$ to the direction of propagation of wave.
   C $60^\circ$ to the direction of propagation of wave.
   D $90^\circ$ to the direction of propagation of wave.

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6. When a wave travels through water, there is transfer of
   A neither energy nor medium particles.
   B both energy and medium particles.
   C only medium particles.
   D only energy.
7. Navy use SONAR method to locate the position of submarine under water. The waves used in SONAR are
   A transverse waves.
   B electromagnetic waves.
   C audible to human ear.
   D audible to navy only.
8. Traffic police checks the speed of the moving vehicles from a distance by using speed gun. This device uses
   A SONAR method.
   B RADAR method.
   C optical fibre.
   D binoculars.
9. A slinky spring is pulled from its free end and released keeping one of its ends fixed. The coils of the spring are found to come closer at some points. Such points are called
   A crests.
   B troughs.
   C rarefactions.
   D compressions.
10. Sound waves require material medium for their transmission. One more example of such wave is
   A Radio waves.
   B Microwaves.
   C Water waves.
   D Ultra-violet rays.

*V. Answer the following questions*

1. What are the different types of waves? Give examples of each type.
2. When light travels from air to glass, the light bends at the interface. What is the reason for this phenomenon of bending of light at the interface of the two media?

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3. Seema could easily hear her echo when she shouted in her school's multipurpose hall. Later she shouted in the same manner in her room at home but she was not able to hear any echo. Explain.
4. There is an explosion on the surface of a lake and two persons Phuntsho and Nado hear its sound. Phuntsho is 150 m away on a boat and Nado is 150 m below the surface of water. Who would hear the sound first and why?
5. Both sound waves and light waves undergo the phenomenon of refraction when they travel from air to water. How is refraction of sound waves different from the refraction of light waves?
6. Maya uses a tuning fork of frequency 250 Hz to produce transverse wave on a stretched string. Her friend Wangmo measures the distance between the two consecutive crests on the string as 5 cm. What was the velocity of the wave?
7. X-rays are used in hospitals to locate fracture in the patient's bones. If the X-rays of wavelength of $2\times10^{-9}$ m travel at a speed of $3\times10^{8}$ m/s in air, what will be its frequency?
8. Complete Figure 6.16.

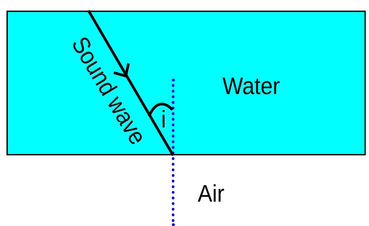


*Figure 6.16*

9. Figure 6.17 shows a displacement-distance graph of a wave. If the velocity of the wave is 330 m/s, determine the wavelength, frequency and amplitude of the wave.

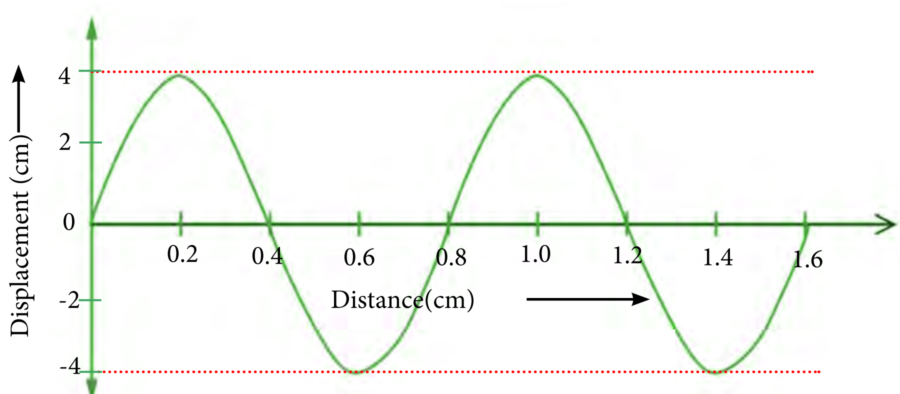


*Figure 6.17*

10. Karma loves to listen to her favourite radio station Kuzu FM. The station broadcasts radio signals with a frequency of $1.07 \times 10^{8}$ Hz. The radio signals travel through the air at a speed of $3 \times 10^{8}$ m/s. What is the wavelength of these waves?
11. Lightning is seen 3 seconds before a thunder. How far away has the thunder taken place? Take velocity of the sound = 340 m/s.
12. Ultrasonic waves are used to locate a sunken ship under the sea. If the reflected wave is received by the receiver after 12 seconds, how far is the ship under water? Take the velocity of sound in water as 1450 m/s.
13. How is SONAR method different from RADAR method?
14. State three uses of ultrasound.
15. Explain the following:
    (a) Sounds are heard clear at night.
    (b) Nocturnal animals can find their prey in darkness.

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7

# The Earth and Beyond

A branch of science that deals with study of universe and its evolution is cosmology. The word '*cosmology*' comes from a Greek word '*cosmologia*', which means orderly arrangement. People engaged different forms of beliefs of religion, philosophy and science to explain about the universe. Accordingly, different theories and perspectives were used to explain the cosmology. Some of the prominent philosophers were like *Aristarchus*, *Aristotle* and *Ptolemy*. Ptolemy's theory of the Earth-Centric system states, the Earth is in the centre of the universe and the Sun, the Moon, and other planets revolve around the Earth. The movement of heavenly bodies was better explained by this theory.

It were *Copernicus*, *Kepler* and *Galileo* who espoused the theory of Sun-Centric system in the 16th century. This theory espouses that the Sun, not the Earth is at the centre of the Solar System. Kepler suggested a particular pattern of the path of the orbit in which planet revolved around the Sun. *Isaac Newton* published a book called '*Principia Mathematica*' in 1687, which proposed that the heavenly bodies moved in the universe. He provided a physical mechanism for Kepler's laws of planetary motion.

## 1. The Universe

### Learning Objectives

On completion of this topic, you should be able to:

- describe universe and galaxies in our universe.
- identify and draw constellations.
- describe asteroids, comets, meteors and meteoroids.

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Our universe is a large and unimaginable expanse of dust, gas, stars, clouds, galaxies, and life. The universe is believed to be at least 10 billion light years in diameter and contains a vast number of galaxies. According to Big Bang Theory, universe has been expanding since its creation about 13 billion years ago.

## A. Galaxy

A galaxy is a large group of stars, dust, gas and dark matter held together by gravity. They vary in size and shape with some containing millions of stars.

After the Big Bang, the Universe was composed of radiation and subatomic particles. What happened next is a big question - did small particles slowly team up and gradually form stars, star clusters, and eventually galaxies? Or did the Universe first organize as immense clumps of matter that later subdivided into galaxies?

On very large scales, galaxies are the building blocks of the universe, as fundamental to astrophysics as ecosystems are to the environment.

There are three main types of galaxies: Elliptical, Spiral, and Irregular.

### *i. Elliptical galaxies*

Elliptical galaxies are shaped like an elongated sphere, or spheroid. In the elliptical galaxies, the light is smooth, with the surface brightness decreasing as you go farther out from the center. Elliptical galaxies have no particular axis of rotation. Elliptical galaxies are classified based on their ellipticity. Ellipticity is the elongation of the shape of galaxies from a perfect circle. The larger the number of ellipticity, the more elliptical the galaxy is. For example a galaxy of classification of E0 appears to be perfectly circular, while a classification of E7 is very elongated and flattened. The elliptical scale varies from E0 to E7.

Figure 7.1 Elliptical galaxy M87

### *ii. Spiral galaxies*

Spiral galaxies have three main components: a bulge, disk, and halo. The bulge is a spherical structure found in the center of the galaxy. This feature mostly contains older stars. The disk is made up of dust, gas, and younger stars. The disk forms arm structures.

The halo of a galaxy is a loose, spherical structure located around the bulge and

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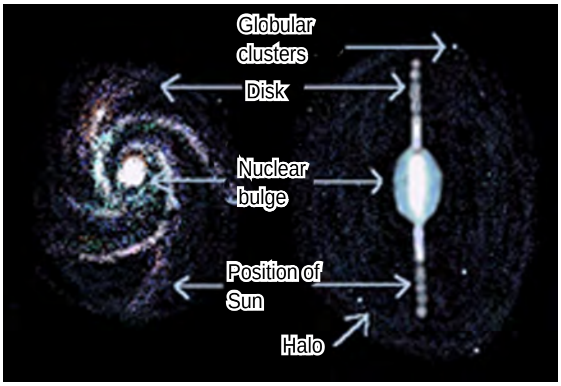

Figure 7.2 Spiral galaxy

some of the disk. The halo contains old clusters of stars, known as globular clusters.

Spiral galaxies are classified into two groups, ordinary and barred. The ordinary group is designated by S or SA, and the barred group by SB. In normal spirals (Spiral galaxy M100) the arms originate directly from the nucleus, or bulge, whereas in the barred spirals (Spiral galaxy NGC 1365) there is a bar of material that runs through the nucleus that the arms emerge from. Both of these types are given a classification according to how tightly their arms are wound. The classifications are a, b, c, d ... with "a" having the tightest arms. In type "a", the arms are usually not well defined and form almost a circular pattern. Sometimes you will see the classification of a galaxy with two lower case letters. This means that the tightness of the spiral structure is halfway between those two letters.

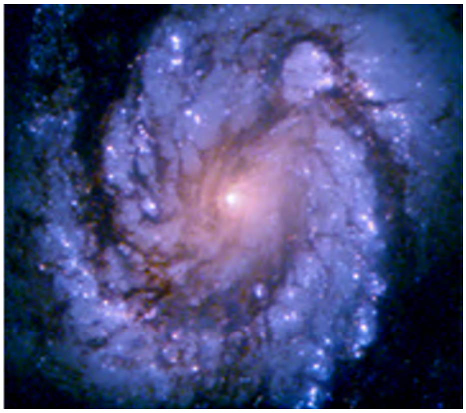
Figure 7.3 Spiral galaxy M100

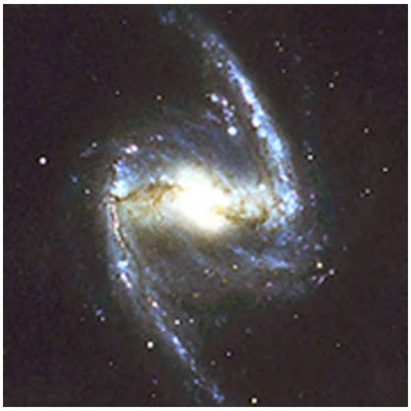
Figure 7.4 Spiral galaxy NGC 1365

Figure 7.5 Milky Way

Our galaxy, the Milky Way has hundreds of billions of stars, enough gas and dust to make billions more stars, all held together by gravity. Our Sun is located in an arm of our galaxy, the Milky Way.

Like more than two-thirds of the known galaxies, the Milky Way has a

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spiral shape. At the center of the spiral, a lot of energy and occasionally vivid flares are being generated. Based on the immense gravity that would be required to explain the movement of stars and the energy expelled, the astronomers conclude that the center of the Milky Way is a supermassive black hole.

### *iii. Irregular Galaxies*

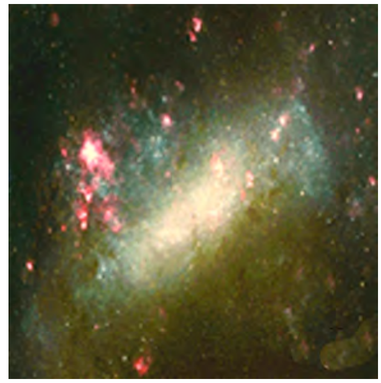
Figure 7.6 Irregular galaxy

Irregular galaxies have no regular or symmetrical structure. They are divided into two groups, Irr I and Irr II. Irr I type galaxies have regions of elemental hydrogen gas, and many young hot stars. Irr II galaxies simply seem to have large amounts of dust that block most of the light from the stars. All this dust makes it almost impossible to see distinct stars in the galaxy.

## B. Constellations

A constellation is a group of visible stars that form a pattern when viewed from Earth. The pattern they form may take the shape of an animal, a mythological creature, a man, a woman, or an inanimate object such as a microscope, a compass, or a crown. For example, Orion is one of the most visible constellations and because of its location, it can be seen throughout the world. Orion is named after a hunter from Greek mythology. The Draco constellation can be viewed in the northern hemisphere. It means "dragon" in Latin.

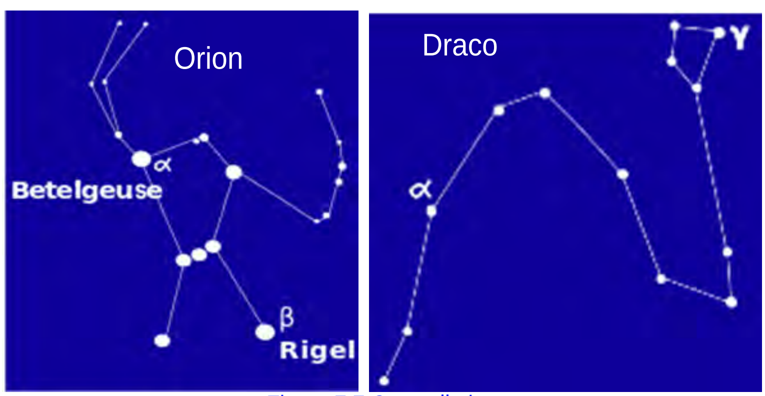

Figure 7.7 Constellation

The constellations are totally imaginary things that poets, farmers and astronomers have made up over the past 6,000 years and more. On a really dark night, you can see about 1000 to 1500 stars. Trying to tell which is which is hard. The constellations help by breaking up the sky into more manageable bits. They are used as mnemonics, or memory aids. Around the world, farmers know that most crops are planted in the spring and harvested in the fall. But in some regions, there is not much differentiation between the seasons.

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Since different constellations are visible at different times of the year, you can use them to tell what month it is. Some historians suspect that many of the myths associated with the constellations were invented to help the farmers remember them. When they saw certain constellations, they would know it was time to begin the planting or the reaping. Constellations were also used in navigation. This dependence on the sky became a strong part of many cultures.

## Activity 7.1 My Constellations

Materials required: "Dove Constellation" and "Horse Constellation" handouts., graph paper.

Dove Constellation

Horse Constellation

Instruction

**Step 1** ☞ Take any one constellation handout and join the dots so that it takes the shape of a dove or a horse.

**Step 2** ☞ Take a graph paper and draw the dots at an exact location as shown in above constellations. Join the dots such that you come up with another animal other than a dove or a horse. Present it in your classroom.

**Step 3** ☞ In a clear and starry night, take a graph paper and observe the bright stars. On the graph paper, mark the position of bright stars with the dots.

**Step 4** ☞ Join the dots such that you come up with shapes that represent animals, humans or objects. Present your work in your classroom.

**Answer the following questions:**

1. How different is the position of stars in "Dove Constellation" and "Horse Constellation"?
2. "Constellations are imaginary". Justify the statement.

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## C. Asteroids

Figure 7.8 Asteroid

An asteroid is a celestial body that orbits the Sun, which is composed of rock, metal or a mixture of both too small to be called planets. They are also known as planetoids or minor planets. Asteroids are material left over from the formation of the solar system. One theory suggests that they are the remains of a planet that was destroyed in a massive collision long ago. Most of them are in the asteroid belt between Mars and Jupiter. Even though there are millions of asteroids with sizes up to more than 500 km (like Pallas and Vesta) they are of no danger to the planet Earth. The biggest body (Ceres) in the asteroid belt is officially not called an asteroid anymore but a dwarf planet. The scale of the solar system is so immense that even inside the asteroid belt the average distance between two asteroids is above one million km - or three times the distance between Earth and the Moon.

Some asteroids have very elliptical trajectories, crossing the orbits of the inner planets Mars, Earth or Venus. The cause of these elliptical trajectories could be collisions within the asteroid belt or the gravitational influence of the massive planet Jupiter changing the orbits of some asteroids gradually over time. All asteroids with eccentric orbits that cross Earth's orbit are called 'Apollo asteroids'. Apollo asteroids are doomed to sooner or later collide with one of the inner planets, usually within a few million years of their orbit becoming so eccentric. The largest Apollo asteroid (1866 Sisyphus) has a diameter of about 9 km.

## D. Comets

Figure 7.9 Comet Lovejoy - NASA

Comets are asteroid-like objects which are composed of ice, dust and rocky particles; that's why they are also called 'dirty snowballs'. The sizes of their nuclei vary between a few hundred metres to tens of kilometres in diameter; their visible tails can extend to above 150 million km in length. They originate from outside Neptune's orbit and like many asteroids and meteoroids, are unmodified remnants of the formation of our solar system about 4.568 billion years ago. When comets approach the Sun the solar radiation and solar winds cause particles to sublimate and detach from the comet, forming a tail of particles which often makes them visible in the night sky even to the naked eye.

Comets orbit around the Sun on elliptical orbits until all of their volatile material has evaporated away. The orbital periods vary

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between a few years (like comet Encke) and tens of millions of years. Short-period comets mainly originate from the Kuiper belt, a region in the solar system with many millions of icy bodies. Comets from the Kuiper belt tend to orbit the Sun within the plane of the solar system because the Kuiper belt itself is aligned with the plane of the solar system.

## E. Meteors and Meteorites

Small pieces of space debris, usually parts of comets or asteroids, that are on a collision course with the Earth are called meteoroids. When meteoroids enter the Earth's atmosphere they are called meteors. Most meteors burn up in the atmosphere, commonly called a "shooting star" or a "falling star". A meteor that is larger and brighter than normal is called a fireball. If these fireballs also break apart or explode during their atmospheric flight accompanied by considerable audible sounds, then they are called a bolide.

If asteroid or meteoroid survive the frictional heating of Earth's atmosphere and strike the surface of the Earth, then they are called meteorites. Meteorites are made of rock (stony meteorites), metal (iron meteorites) or a mixture of these two materials (stony-iron meteorites or pallasites). Pallasites form beautiful olivine crystals that are embedded into a metal matrix.


Figure 7.10 Meteorites

The Earth has been struck by many meteorites, some quite large. Figure 7.11 shows Barringer Crater in Arizona. It is 1.2 kilometers across and 200 meters deep, and was formed about 49,000 years ago by the impact of a 50 meter nickel-iron meteorite travelling at a speed of 11 kilometers per second.

Figure 7.11 Barringer Crater

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## F. Black holes and wormholes


Figure 7.12 A young black hole

Black holes cannot be directly observed with telescopes that detect X-rays, light, or other forms of electromagnetic radiation. However, the presence of black holes are inferred by detecting their effect on other matter nearby. Black holes have extreme density and strong gravitational attraction that even light cannot escape from their grasp if it comes near enough. If a black hole passes through a cloud of interstellar matter, for example, it will draw matter inward in a process known as accretion. A similar process can occur if a normal star passes close to a black hole. In this case, the black hole can tear the star apart as it pulls it toward itself. As the attracted matter accelerates and heats up, it emits X-rays that radiate into space. Recent discoveries offer some tantalizing evidence that black holes have a dramatic influence on the neighbourhood around them, emitting powerful gamma ray bursts, devouring nearby stars, and spurring the growth of new stars in some areas while stalling it in others.

As a star uses up all of its hydrogen and other elements that produce energy through nuclear fusion, the star no longer maintains an internal pressure to expand, and gravity is left unopposed to pull inward and compress the star. For stars above a certain mass, this gravitational collapse will produce a black hole, containing several times the mass of the Sun. In other cases, the gravitational collapse of huge dust clouds may create super massive black holes containing millions, or billions of solar masses.

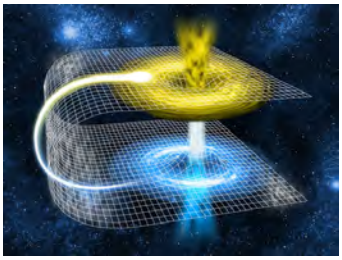
Figure 7.13 Wormhole

The theory of black holes has led to another predicted entity, a wormhole. This is a solution of the field equations that resembles a tunnel between two black holes, or other points in space-time. Such a tunnel would provide a shortcut between its end points. In analogy, consider an ant walking across a flat sheet of paper from point A to point B. If the paper is curved through the third dimension, so that A and B overlap, the ant can step directly from one point to the other, thus avoiding a long trek. The researchers stipulate that wormholes are actually entangled black holes caused by two black holes being created simultaneously.

The possibility of short-circuiting the enormous distances between stars makes wormholes attractive for space travel. Because the tunnel links moments in time, as well as locations in space, it also has been argued that a wormhole would allow travel into the past. However, wormholes are intrinsically unstable.

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## 2. Relative size and position of heavenly bodies

**Learning Objectives**

On completion of this topic, you should be able to:

- compare the relative sizes and positions of heavenly bodies in the universe.

Earth is a member of our Solar System. A solar system consists of a group of heavenly bodies, which include star and planets, and other objects orbiting around it. Our solar system consists of the Sun and the planetary bodies orbiting it, such as the eight, formerly nine planets, three dwarf planets, about 160 known *planetary satellites* (moons), and countless asteroids. The solar system also consists of many icy bodies, and vast amounts of nebula, gas and dust known as the *interplanetary medium*.

Solar system objects are arranged by size in descending order of mean volumetric radius. They can also be partially sorted according to an object's mass, volume, density and surface gravity. The ordering may be different, depending on whether one chooses radius or mass, because some objects are denser than others. For instance Uranus is bigger than Neptune, but has less mass. Ganymede and Titan are larger than Mercury, but they have less than half the mass of Mercury. This means some objects farther away from the Sun, despite their smaller radii, may have more mass than objects closer to the Sun because they have a higher density.

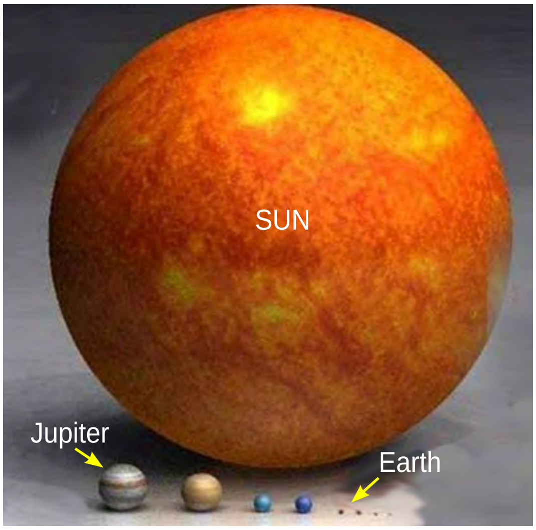


Figure 7.14 Relative size of planets and the Sun

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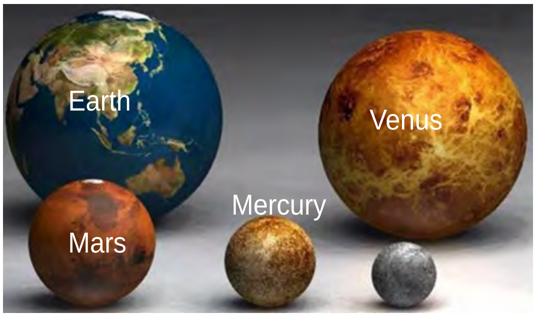


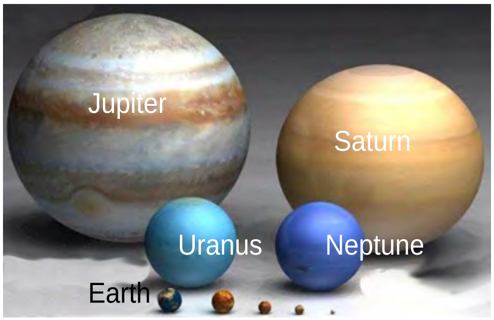


Figure 7.15 Relative size of planets

In the Solar system, mercury is the closest planet to the Sun, and Neptune is the farthest. Our Earth is the third closest planet to the Sun. The distance between the planets and the Sun varies due to the shape of their orbits and their proximity with the Sun. The average distance between the Earth and the Sun is so huge that measurement in units like kilometres and miles bears large numbers and inconvenient to use. So, a bigger unit of measuring distance called *astronomical unit* (AU) is used, instead. Astronomical unit is the average distance of the Sun from the Earth.

i.e. 1 AU = $1.496 \times 10^{11}$m.

This makes the number manageable. Planets further away than the Earth is more than 1 AU, and those closer to Sun from the Earth is less than 1 AU. For instance, Jupiter is 5.2 AU and Pluto is nearly 40 AU away from the Sun. On the contrary, Mercury is 0.38 AU and Venus is 0.72 AU away from the Sun.

There are many ways by which the relative positions of heavenly bodies are determined by measuring their distances. Two basic methods are discussed below.

## A. Parallax Method

If a planet P is seen from the two distinct points on the Earth's surface, say points A and B. The line AB is the basis. D is the distance from the points present on the surface of the Earth to the planet. Calculate the magnitude of the parallax angle, which is the angle formed at point P using the two distances AP and BP as shown in Figure 7.16.

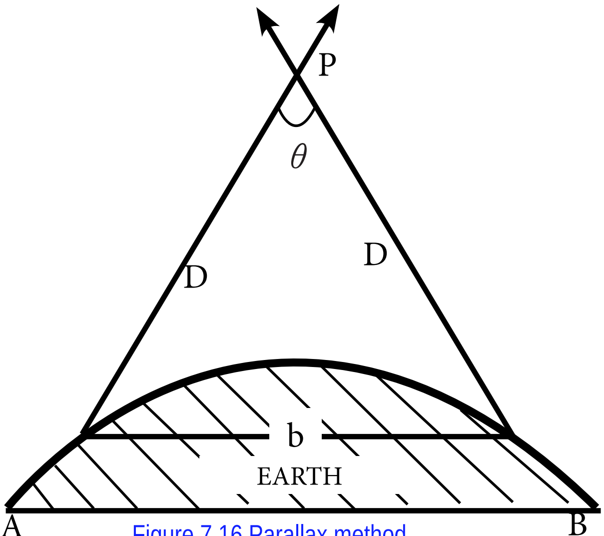


Figure 7.16 Parallax method

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So, $$\theta = \frac{arc(AB)}{radius(PA)} = \frac{b}{D}$$

$$D = \frac{b}{\theta}$$

If in the above equation, angle is in radians and the value of b is in astronomical unit (1 A.U), the distance between the Earth and the planet will come in Astronomical units.

## B. Kepler's Third Law.

Kepler's Third Law method is used to find the distances between the heavenly bodies. Kepler's law can be applied to those bodies, whose orbital track is larger than the Earth's orbit around the Sun.

According to Kepler's law

$$T^2 \propto R^3$$

In the above equation, R represents the semi major axis and T is the time period.

Suppose $R_1$ and $R_2$ are the semi major radii, and $T_1$ and $T_2$ are the time periods then

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3}$$

$$So\ R_2 = R_1\left(\frac{T_2}{T_1}\right)^{\frac{2}{3}}$$

If we have the values of $R_1$, $T_1$ and $T_2$, we can easily find the value of $R_2$.

**Activity 7.2** **What are the prevailing myths of heavenly bodies in the community?**

Instruction:

Many communities hold and practice numerous beliefs related to myths of heavenly bodies. In groups, discuss about the numerous beliefs that different communities practice and have influenced their lives. The following are the suggested areas for discussion.

1. Identify different beliefs about the heavenly bodies in the communities of your group members, or that you have heard and read.
2. How have these beliefs influenced the lives of people in the communities?
3. Explain these beliefs by using scientific ideas.
4. What are the significance of these beliefs in the society?

Present your finding to the class.

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# 3. Astronomical instruments

## Learning Objectives

On completion of this topic, you should be able to:

- describe how the development of technology has helped our knowledge and understanding of the Solar System and the universe as a whole.
- explain telescopes, early satellites, modern space probes and space telescopes.
- construct a simple telescope using two convex lenses.

The study, observation and measurement of celestial bodies in astronomy are mainly done by using astronomical instruments. This helps to find out the size and structure of the celestial bodies. It is very difficult to observe all these bodies clearly using the instruments. Therefore, sometimes it is very useful to collect celestial emissions from the objects like the various radiations.

People observed the sky from ancient times. The astronomical observations helped them in their day to day lives. The Babylonians and the Egyptians together invented calendars. Water clocks and sundials were used in olden times.

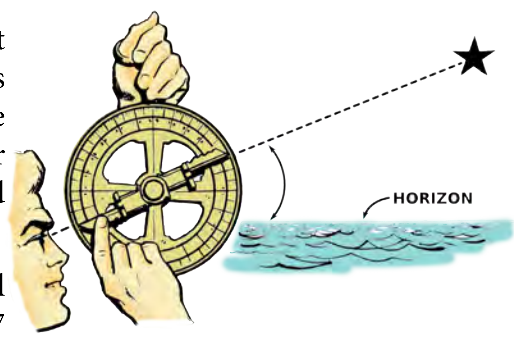

Figure 7.17 Astrolabe

One of the earliest astronomical instruments was an astrolabe. Figure 7.17 shows an astrolabe. The instrument was used mainly to locate and predict the positions of celestial objects like the Sun, the Moon, planets and stars. By knowing the position of heavenly bodies, people could then determine the latitude of a place.

With civilization and development, people invented various sophisticated and accurate instrument that helped to make astronomy more interesting. Some of the modern astronomical instrument are telescopes, satellites and space probes.

## A. Telescopes

One of the basic astronomical instrument is a telescope. A telescope is an instrument used for seeing objects that are very far away. It consists of a tube with a lens at either ends. Some telescopes have one of the lenses replaced with a curved mirror. It is

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believed that Galileo Galilei, an Italian astronomer was the first person to develop the telescope. Telescope helps to observe distant objects by detecting electromagnetic radiations including visible light.


(a) (b)

Figure 7.18 (a) Achromatic reflecting telescope and (b) apochromatic refractor telescope

Telescopes gather and focus light mainly from the visible part of the electromagnetic spectrum. Optical telescopes are of three types namely: refracting telescope, which uses lenses to form images; reflecting telescopes, which uses an arrangement of mirrors to form images; and catadioptric telescopes, which uses combination of mirrors and lenses to form images. Figure 7.18 shows some optical telescopes.

Telescope has the following parts.

a. Objective is a converging lens or mirror which collects light over a wide area and funnels it into a small area in order to enter the eye. Telescopes which have objective lenses, usually converging lenses, are called *refractors*. Telescopes which have objective mirrors, usually concave mirrors, are called *reflectors*. The amount of light gathered depends on the area of the objective. Since objectives are normally circular, the area can be specified in terms of the aperture (D). Therefore, the light gathering power (LGP) = $4\pi D^2$. Thus, the LGP increases as the square of the aperture.

b. Eyepiece is a converging lens, which functions as a magnifying glass and enlarges the image created by the objective. The magnifying power (M) of a telescope, thus depends on both the objective and the eyepiece. Magnifying power is defined as the ratio of the angular size of the image to the angular size of the object. For example, a telescope with an objective focal length of 1000 mm and

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an eyepiece of focal length 20 mm will produce a magnification as given below.

$$Magnification = \frac{Focal\ length\ of\ Objective}{Focal\ length\ of\ eyepiece}$$

$$Magnification = \frac{1000\ mm}{20\ mm} = 50X$$

Resolution of a telescope is affected by an aperture and the wavelength of the light being used. Therefore, it is higher for larger apertures and shorter wavelengths. Resolving power is specified as the minimum angular separation, which the telescope can resolve. Once this limit is reached, increasing the magnification will not improve telescope performance.

## Activity 7.3 Constructing a simple telescope

Materials required:

For each student or group of students:

- Telescope mount or metre rule with Plasticine or Blu-Tack.
- Retort stand.
- Convex lens or plano-convex (focal length = 5 cm).
- Convex lens or plano-convex (focal length = 25 cm).
- Paper screen.
- 200 W carbon filament lamp.
- Mounted lamp holder.

### Procedure

**Step 1** ☞

Put 25 cm focal length lens in a holder at the far end of the mount or fix it firmly to the metre rule with Plasticine or Blu-Tack. If it is plano-convex, the convex face should be towards the object.

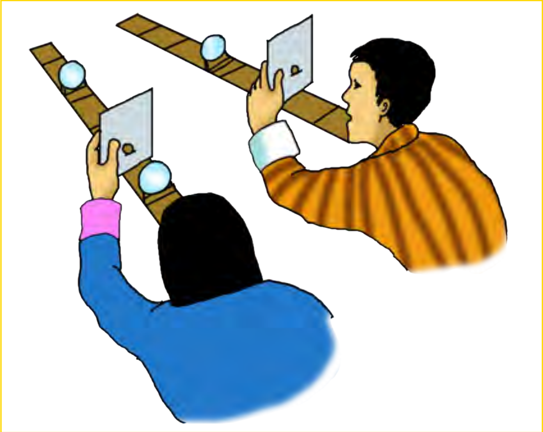

Figure 7.19

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**Step 2** ☞

Raise the telescope mount to shoulder height. Turn and tilt the mount until it is aimed at the distant lamp. Catch the real image of the filament on the paper screen like the back of the pinhole camera.

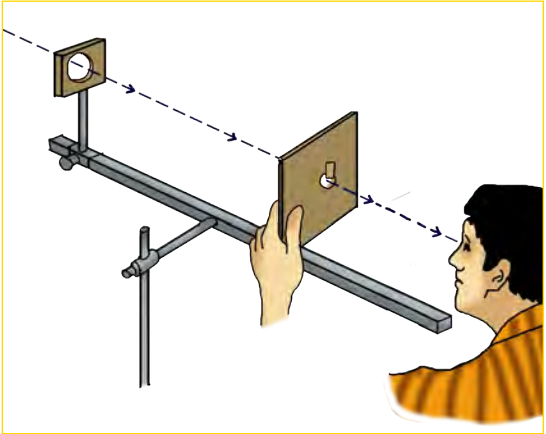

Figure 7.20

**Step 3** ☞

Install the eyepiece of focal length 5 cm, as a magnifying glass to view the paper screen with one eye. Again, if a plano-convex lens is used, the convex face should be towards the paper screen. (The system is not symmetrical.)

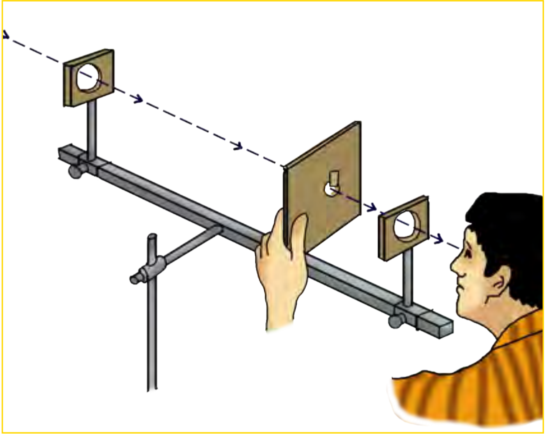

Figure 7.21

**Step 4** ☞

Take away the paper screen, so that you are looking through a telescope at the lamp, with one eye.

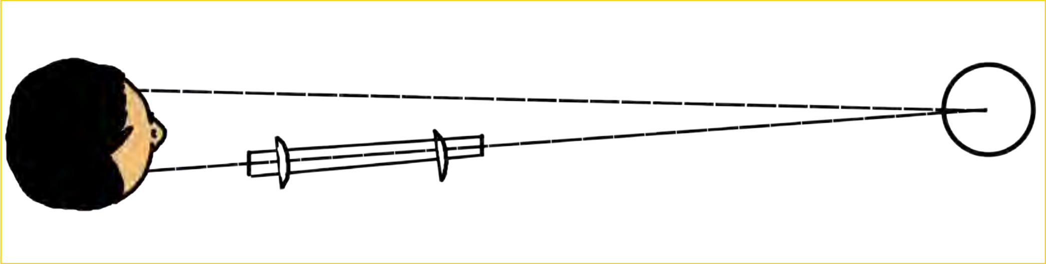

Figure 7.22

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**Step 5** ☞

Open the other eye and use your two eyes to get the telescope properly focused. For comfortable use, the final image should be as far out as the object.

View the image of the distant lamp through the telescope with one eye and view the lamp with the other eye without the telescope.

Does the telescope picture of the lamp look larger than the picture seen by the naked eye?

If they are not in focus at the same time, move the eyepiece forward or backward a little until you see both clearly at the same time.

**Step 6** ☞ Direct the telescope outside the window and look at familiar objects. DO NOT LOOK AT THE SUN.This could damage students' eyes badly.

**Answer the following questions:**

1. Draw the setup and identify the objective and eyepiece.
2. Describe the nature of the image formed.
3. What is the magnification of the telescope?
4. What are the limitations of your telescope?

## B. Advancement in telescope

With an incremental interest of people around the world to study about the heavenly bodies in the solar system, great advancement in telescope was witnessed. The following activity illustrates this.

**Activity 7.4** **Exploring different types of Telescopes**

Read the following text on "Timeline of Telescope". Discuss in your group and answer the questions that follow.

### Timeline of Telescope

In 1608, Hans Lippershey, a German Dutch lensmaker once said that he wanted to make an instrument "for seeing things far away as they were nearby." He was the first person to ever think of the telescope.

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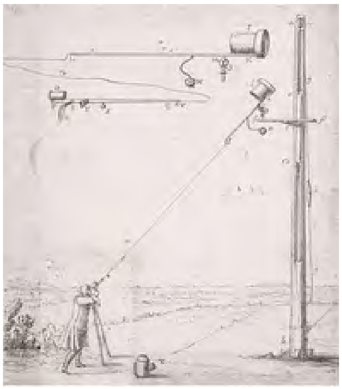
On hearing about this new instrument, in 1609, an Italian physicist Galileo Galilei builds his own. He improved Lippershey's design and using his new telescope the following year, he discovers the four largest moons of Jupiter (Io, Ganymede, Callisto and Europa), sunspots on the surface of the Sun, the phases of Venus and physical features on the Moon, such as craters!

In 1616, an Italian priest and astronomer Niccolo Zucchi creates a concave spherical to magnify objects and he used it to discover Jupiter's belts 14 years later.

In 1630, a German priest and astronomer Christoph Scheiner builds a telescope based on a design that astronomer Johannes Kepler made in 1611. Kepler's design improves on Galileo's by replacing the concave lens with a convex lens which gave perfect images when they look through their telescopes.

Inspired by the observations of Jupiter made by Galileo, in 1655, Dutch astronomer Christian Huygens builds the most powerful telescope ever and uses it to view the planets in our Solar System. He spotted a bright moon in orbit around Saturn and called it "Saturni Luna." All astronomers used this name until 1847, when John Herschel (famous astronomer William Herschel's son) decided that the moon should be called Titan. Huygens studied Saturn much more with his telescope and discovered the true shape of the planet's rings in 1659.



After studying the reflection of light through prisms, Sir Isaac Newton decides to make an improved version of the reflecting telescope in 1666.

In 1672, Laurent Cassegrain, a catholic priest from France, develops a telescope that bears his name, the Cassegrain telescope. This instrument uses mirrors that are called hyperbolic and parabolic mirrors.

The year 1729 saw a huge development in refracting telescope. During this time, lawyer Chester Moore Hall makes a lens to reduce chromatic aberration even further. He made the lens by cementing two types of glass (crown and flint) together.

In 1789, Bath,Orchestra Director and astronomer William Herschel builds a Newtonian based

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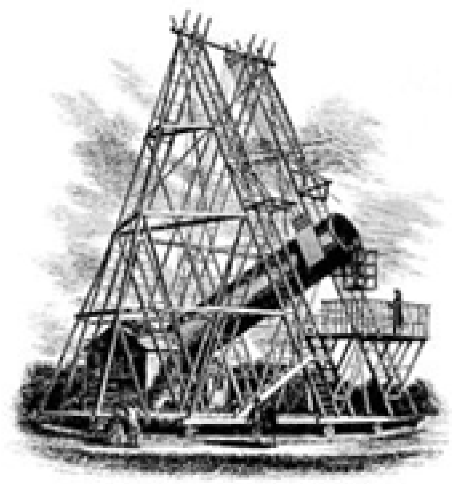
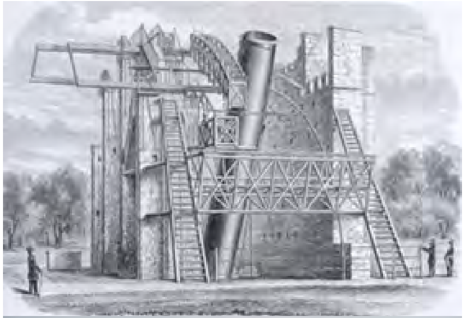
reflector telescope, which is a gigantic 12 metres. It was the first of the giant reflector telescopes.



In 1845, “Leviathan of Parsonstown” at Birr Castle in Ireland was built in this year by the Third Earl of Rosse, William Parsons. It was the largest telescope ever built until the twentieth century. Parsons was the first person to see spiral arms on a galaxy!



In 1897, an American astronomer Alvan Clark builds the first world’s largest existing refracting telescope, the Yerkes Telescope in Wisconsin. Because this telescope holds the largest glass lens possible before a telescope will begin to buckle under its own weight, astronomers decided that large telescopes should have mirrors instead of lenses.

Inspired by sky survey work by Karl Jansky, in 1937, an American engineer Grote Reber takes the telescope into a whole new dimension: the radio telescope. Reber created an instrument that could basically see radio waves invisible to our eyes.

Astronomer Sir Bernard Lovell planned a 250 ft radio telescope that could be pointed to anywhere in the sky in the 1950s. After a series of technical and financial problems, it was finally built and ready to be used in the summer of 1957. The telescope can be visited at Jodrell Bank in the UK.

In 1990, NASA and ESA’s Hubble Space Telescope was the first telescope to be launched into space. Above the turbulence of the Earth’s atmosphere, Hubble gives us a very clear view of the stars and planets right to this very day!

The Compton Gamma Ray Observatory becomes the first space telescope to look at objects that belch out high energy waves called gamma rays in 1991.

The W. M. Keck Observatory, a two-telescope astronomical observatory, is built near the summit of Mauna Kea in Hawaii at an

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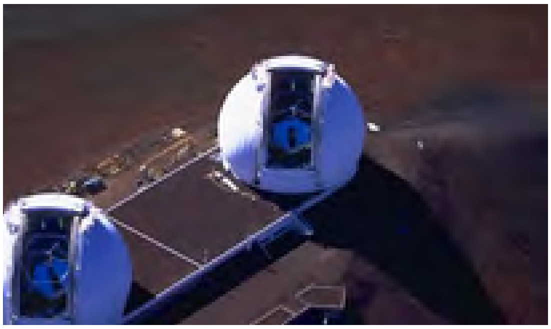

Courtesy W. M. Keck Observatory

Gran Telescopio Canarias

incredibly dizzy height of 13,600 feet in 1995. They are the second largest optical telescopes in the world.

In 2009, the Herschel Space Observatory is launched. Bearing the name of astronomer, William Herschel, this space observatory is able to look into the really cold regions of space with its far infrared vision!

In 2010, the Gran Telescopio Canarias is built on the island La Palma in the Canary Islands of Spain on the top of a volcanic peak 7,438 feet above sea level. It is the largest telescope of our time.

*Source: http://www.kidsastronomy.com/telescopesD.htm*

**Question**

1. Who was first person who envisaged a telescope to see the objects far away?
2. Why are telescopes constructed either on mountains, or high towers?
3. What are your assumptions to account on the increase in size of telescope over the time?
4. Differentiate telescope from binocular.
5. What is the significance of study of solar system?

## C. Exploration of Space

Since prehistoric times, curiosity about the Earth, the planets and stars has been the driving force behind human progress. Looking out into space at the Sun and stars and measuring their progression has been a key part of human progress for thousands of years. Today, the exploration of the universe beyond the confines of our home planet is one of the most inspiring, exciting and fruitful areas of scientific research. Many studies require sending spacecraft into space, mostly unmanned. One of the main advantages of investigating the universe from space is that the details of far-off galaxies, as well as events marking the birth, evolution and death of stars, can be seen unhampered by the blurring effects of the atmosphere, and at

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wavelengths of light not easily accessible from the ground providing new insights into astrophysical processes. Increasingly, scientists and engineers are developing advanced space probes, with robotic components that can operate autonomously, to explore the extraordinarily diverse planets and moons of our solar system and find Earth-like planets around other stars.

Many space missions are designed to look back at the Earth, to study its rich complexity and the effects of humans on the terrestrial environment and provide insights into the Earth's own geology and meteorology, and on how life evolved.

Satellite services are one of the fastest-growing areas of advanced technology. It is now hard to imagine modern life without satellite communications – for entertainment, information, security, environmental monitoring, etc. Observations from space can follow weather patterns. They can provide an understanding of hurricane formation, so that early-warning systems can be implemented. Images from space can show the best routes for access into areas cut off by flooding and other environmental disasters.

Since Galileo and his contemporaries used 16$^{th}$ century technology to explore the cosmos, astronomers are using 21$^{st}$ century cutting-edge technology to push our understanding of an increasingly strange and exciting universe. Just as in Galileo's time, modern telescopes are a synthesis of the most advanced scientific thinking and engineering skill.

### *i. Space telescope*

The modern telescopes are the outcome of the most advanced scientific thinking and engineering skill. The world has managed to put the most advanced telescopes above the Earth's atmosphere. In space, the distortion and absorption by air is absent. Therefore, the universe shines brightly from one end of the electromagnetic spectrum to the other.

A few of NASA's space telescopes are illustrated in the Table 7.1.

| Space telescope | |
|---|---|
|  Hubble orbiting 350 miles above a cloudy ocean. Credit: NASA | **Hubble Space Telescope (HST)**<br>Placed into orbit to overcome the scourge of astronomers throughout time - the blurring of starlight by our atmosphere. The school bus sized HST has given us the most crystal-clear and beautiful images of the universe. |

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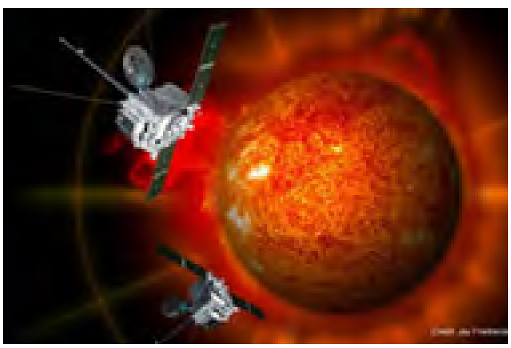
| | |
|---|---|
|  Artist's rendering of the Chandra X-ray Observatory in orbit. Credit: NASA | **Chandra X-ray Observatory** Chandra detects high energy light called X-rays. X-ray telescopes reveal the most extreme events in our universe, like exploding stars and matter falling into black holes. |
|  Artist's rendering of the Spitzer Space Telescope in space. Credit: NASA | **Spitzer Space Telescope** We can feel heat, but the Spitzer Space Telescope sees heat! Some objects in space are too cold to glow in visible light, but still radiate plenty of lower energy infrared light. Vast clouds of interstellar dust and gas, the raw materials for the next generation of stars, are dark and unseen by optical telescopes but shine brightly for Spitzer's infrared detectors. |
|  Artist's rendering of the STEREO spacecraft orbiting the Sun. Credit: NASA | **STEREO** A pair of orbiting telescopes stare at the Sun, giving us a 3-D view of the Sun's surface. STEREO continues a long tradition of solar observations dating back to Galileo himself. |

**Source: http://astronomy2009.nasa.gov/topics_jan.htm**

### *ii. Space probes: the great explorers of modern times*

Modern space technology has opened up a second front of exploration, allowing humans and robots to travel to some of the worlds that Galileo studied with his spyglass. The space probes and landers that explore our solar system at the beginning of the new millennium are part of a continuing quest to know our place in the galaxy.

Space probes fly over hostile environments, sending back pictures, landing where human beings cannot go, and they bring back data and samples for analysis. These fabulous devices add to our knowledge of planets, comets, asteroids and many other bodies.

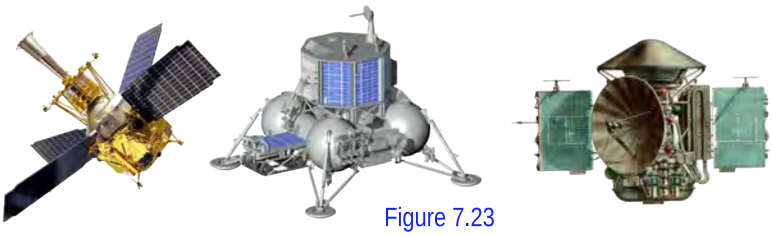


Figure 7.23

They have names like Pioneer, Voyager, Galileo, Magellan and Ulysses. They are the explorers of our times, successors to Marco Polo, Christopher Columbus, and Ferdinand Magellan, who explored our globe. These modern explorers are robots; as substitutes for our eyes and other senses, they have transformed our ideas about the solar system in a single generation.

Space probes are among our most ingenious technological inventions. They must not only travel hundreds of millions of kilometers in the hostile environment of interplanetary space, but also complete all mission maneuvers, including landing, using onboard computers, with no assistance from Earth. A typical probe has two modules: an orbiter and a lander.

## Questions

1. What is a space telescope? What are its uses?
2. The pioneer telescope mainly consisted of lenses. Over the time, lenses were replaced by mirrors. What were the reasons?
3. What type of telescope has been developed to study the objects that are either not visible to people, or harmful to observe directly?
4. Why do scientists explore space?
5. Why are space probes more effective than the use of space telescopes?

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## Summary

- A branch of science that deals with study of universe and its evolution is cosmology.
- A galaxy is a large group of stars, dust, gas and dark matter held together by gravity.
- There are three main types of galaxies: Elliptical, Spiral, and Irregular.
- A constellation is a group of visible stars that form a pattern when viewed from Earth.
- An asteroid is a celestial body that orbits the Sun, which is composed of rock, metal or a mixture of both that is too small to be called planets. They are also known as planetoids or minor planets.
- Comets are asteroid-like objects which are composed of ice, dust and rocky particles.
- An asteroid or meteoroid that survives the frictional heating of the Earth's atmosphere and strike the surface of the Earth is called a meteorite.
- Black holes have very high density and strong gravitational attraction that even light cannot escape from their grasp if it passes close to them.
- The wormholes are actually entangled black holes created simultaneously that resembles a tunnel between two black holes.
- The study, observation and measurement of celestial bodies in astronomy are mainly done by using astronomical instruments such as telescopes and space probes.
- Space probes must not only travel hundreds of millions of kilometers in the hostile environment of interplanetary space, but also complete all mission maneuvers, including landing, using onboard computers, with no assistance from Earth.

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## Exercises

***I. Fill in the blanks.***

1. The researchers stipulate that ………….. are actually entangled black holes.
2. The telescopes are important for …………..
3. Stars, comets, asteroids, Venus are heavenly bodies, but Venus is a …………..
4. …………..telescope is useful to study the Sun.
5. The space between black holes is called…………..

***II. State whether the following statements are 'True' or 'False' and correct the false statements:***

1. Spherical mirrors produced better images than the lenses in the telescope.
2. Our galaxy, Milky Way is a spiral galaxy.
3. As per the theory of wormhole, a person can travel through different time period.
4. If asteroids or meteoroids survive the frictional heating of the Earth's atmosphere and strike the surface of the Earth, they are called meteors.
5. The constellations are real.

***III. Match the following.***

| Column A | Column B |
|---|---|
| 1. An orbiter and a lander | (a) Astronomical Unit (AU) |
| 2. Stars, dust, gas and dark matter held together by gravity | (b) Meteorites |
| 3. Average distance of the Sun from the Earth | (c) Space probes |
| 4. Asteroid or meteoroid striking surface of the Earth | (d) Constellations |
| 5. Used in navigation | (e) Galaxy |
| | (f) Black holes |
| | (g) Comet |

***IV. Multiple choice questions.***

1. Telescope is an important instrument in the study of solar system, because it
   - A can measure the temperature of planets.
   - B make far objects visible.
   - C protects our eyes from UV radiations.

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D can be carried by rockets.

2. The focal length of an eyepiece is
   A shorter than that of objective to form an image in the telescope.
   B longer than that of objective to form an image in the telescope.
   C short so that large image is formed.
   D short so that small image is formed.
3. When heavenly bodies lose their energy, they are devoured by
   A wormhole.
   B galaxy.
   C constellation.
   D black hole.
4. Magnification is the ratio of
   A focal length of objective to eyepiece lens.
   B focal length of eyepiece to objective lens.
   C length of telescope to height.
   D length of telescope to focal length of objective lens.
5. The image formed in the telescope is
   A inverted and magnified.
   B magnified and erect.
   C erect and diminished.
   D inverted and diminished.
6. If the Sun were suddenly to become a black hole
   A all the planets would go flying off into interstellar space.
   B all the planets would be sucked into the black hole.
   C Mercury (the closest planet) would be sucked into the black hole, but no other planets would.
   D the planets would continue orbiting the black hole as if nothing happened.

V. *Answer the following questions.*

1. Define cosmology.
2. What is the significance of blackhole in cosmology?
3. Explain a method of finding the location of a planet from the Earth.
4. What are the ways by which scientists study universe?

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5. Read the following text and answer the following questions.

### Black holes do NOT exist and the Big Bang Theory is wrong

*-Professor Laura Mersini-Houghton from the University of North Carolina at Chapel Hill in the College of Arts and Scientists.*

During the collapse process stars release a type of radiation called Hawking radiation (shown). But Professor Mersini-Houghton claims this process means the star loses too much mass and can't form a black hole. And this also apparently means the Big Bang theory, that the universe began as a singularity, may not be correct.

Article By JONATHAN O'CALLAGHAN FOR MAILONLINE

When a huge star many times the mass of the sun comes to the end of its life it collapses in on itself and forms a singularity - creating a black hole where gravity is so strong that not even light itself can escape.

At least, that's what we thought.

A scientist has sensationally said that it is impossible for black holes to exist - and she even has mathematical proof to back up her claims.

If true, her research could force physicists to scrap their theories of how the universe began.

The research was conducted by Professor Laura Mersini-Houghton from the University of North Carolina at Chapel Hill in the College of Arts and Scientists.

She claims that as a star dies, it releases a type of radiation known as Hawking radiation - predicted by Professor Stephen Hawking.

However in this process, Professor Mersini-Houghton believes the star also sheds mass, so much so that it no longer has the density to become a black hole.

Before the black hole can form, she said, the dying star swells and explodes.

The singularity as predicted never forms, and neither does the event horizon - the boundary of the black hole where not even light can escape.

'I'm still not over the shock,' said Professor Mersini-Houghton.

'We've been studying this problem for a more than 50 years and this solution gives us a lot to think about.'

Experimental evidence may one day provide physical proof as to whether or not black holes exist in the universe.

But for now, Mersini-Houghton says the mathematics are conclusive.

What's more, the research could apparently even call into question the veracity of the Big Bang theory.

Most physicists think the universe originated from a singularity that began expanding with the Big Bang about 13.8 billion years ago.

If it is impossible for singularities to exist, however, as partially predicted by Professor Mersini-Houghton, then that theory would also be brought into question.

One of the reasons black holes are so bizarre is that they put two fundamental theories of the universe against each other.

Namely, Einstein's theory of gravity predicts the formation of black holes. But a fundamental law of quantum theory states that no information from the universe can ever disappear.

Efforts to combine these two theories proved problematic, and has become known as the black hole information paradox - how can matter permanently disappear in a black hole as predicted?

Professor Mersini-Houghton's new theory does manage to mathematically combine the two fundamental theories, but with unwanted effects for people expecting black holes to exist.

'Physicists have been trying to merge these two theories - Einstein's theory of gravity and quantum mechanics - for decades, but this scenario brings these two theories together, into harmony,' said Professor Mersini-Houghton.

'And that's a big deal.'

i. Why do Professor Mersini-Houghton believe that it is impossible for black hole to exist?

ii. If you agree with Professor Mersini-Houghton, then explain the wormhole.

iii. How do Einstein's theory of gravity and quantum theory contradict each other?

iv. Why cannot a star become a black hole?

v. What do you think about the existence of a black hole?

6. What is the difference between a meteorite, a meteoroid and a meteor? How do these differ from an asteroid?
7. Name the composition of a comet.
8. How did the constellations get their names?
9. How does Kepler's law help to explain planetary motions?
10. Why do you think there are several myths of heavenly bodies?
11. Explain the basis of astronomical unit.

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## Specimen Question Paper

**Physics** | **Writing Time**: 2 Hours
**Class IX** | **Total Marks**: 100

**READ THE FOLLOWING DIRECTIONS CAREFULLY:**

1. Do not write during the first fifteen minutes. This time is to be spent on reading the questions. After having read the questions, you will be given two hours to answer all questions.
2. In this paper, there are two sections: A and B. Section A is compulsory. You are expected to attempt any five questions from Section B.
3. The intended marks for questions or parts of questions, are given in brackets [ ].
4. Read the directions to each question carefully and write all your answers in the answer sheet provided separately.

**Section A (50 Marks)**

*Compulsory: Attempt* **all** *questions.*

### Question I

a. *Each question in this section is provided with four possible options. Choose the most appropriate option.* [1×25=25]

i. A body is moving with negative acceleration. Which one of the following statements are true in the context of this body?

A. The body is starting to move.
B. The body is falling freely on the ground.
C. The body is coming to a halt.
D. The body is moving with constant velocity.

ii. Dechen was using a hydrometer to measure certain property of a liquid. The property of the liquid she is measuring is

A. temperature.
B. density.
C. pressure.
D. volume.

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iii. When heavenly bodies lose their energy, they collapse into a

A. worm hole.

B. galaxy.

C. constellation.

D. black hole.

iv. While observing an aircraft flying in the atmosphere through an instrument, an inverted and magnified image was seen. The instrument used for this observation is

A. microscope.

B. telescope.

C. periscope.

D. binocular.

v. While swimming in the river, Kailash found himself being pushed up by the water helping him to float. What is the name of the force that was pushing Kailash in the upward direction?

A. Gravitational force.

B. Air resistance .

C. Buoyant force.

D. Resultant force.

vi. A 5 kg object is accelerating uniformly with 0.5 $ms^{-2}$ from the rest position for 10 s. Find the change in momentum of the object.

A. 25 kg $ms^{-1}$

B. 32 g $ms^{-1}$

C. 30 g $ms^{-1}$

D. 31 kg $ms^{-1}$

vii. The latent heat of fusion is measured in

A. J/kg°C.

B. cal/g.

C. cal/g°C.

D. J/°C.

viii. A nurse while recording temperature of a sick man reads 99.5 degree F. If you are to measure the temperature in degree Celsius, what will be the reading?

A. 35.5 degree Celsius.

B. 36.6 degree Celsius.

C. 37.5 degree Celsius.

D. 39.9 degree Celsius.

ix. Deki uses a piece of silk cloth to rub a plastic comb. The comb then becomes positively charged because it

A. loses electrons.

B. gains electrons.

C. loses protons.

D. gains protons.

x. The speed of rotation of a d.c. motor does **not** depend upon the

A. strength of the current.

B. size of the commutator.

C. number of turns of the armature coil.

D. strength of the applied magnetic field.

xi. When the light from the sun travels through air, the dispersion of light does not take place. This is because the

A. speed of light is minimum in air.

B. speed of light is maximum in air.

C. different colours of light have same speed in air.

D. different colours of light have different speed in air.

xii. When a ray of light passes from one medium to another medium, the property of light that does not change is

A. frequency.

B. intensity.

C. velocity.

D. wavelength.

xiii. If a certain mass of water is cooled slowly from 15˚C to 0˚C, its volume

A. decreases continuously.

B. increases continuously.

C. first decreases and then increases.

D. first increases and then decreases.

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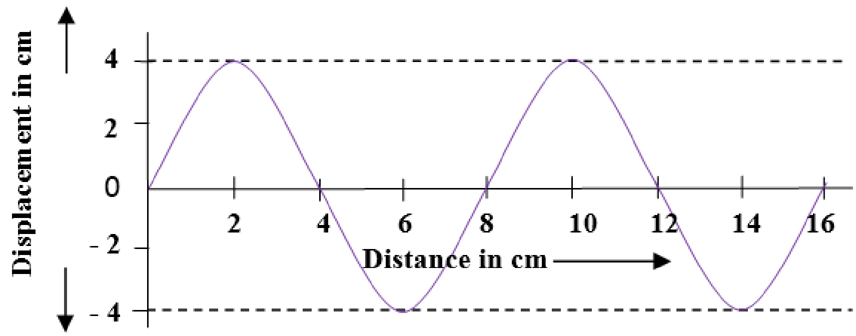
xiv. A transverse wave is shown in figure below. The amplitude and wavelength of the wave are




A. 1 cm and 1 cm respectively.
B. 2 cm and 2 cm respectively.
C. 2 cm and 4 cm respectively.
D. 4 cm and 8 cm respectively.

xv. Suppose a piece of wood is floating on the surface of a pond. You throw a small stone into the pond and create a ripple of waves. When the waves passes below the wood, it pushes the wood up and down. The wood does not move along the direction of the waves but rather moves perpendicular to the waves. The type of waves created in the pond is

A. longitudinal waves.
B. transverse waves.
C. ultrasonic waves.
D. both transverse and longitudinal waves.

xvi. The equation v=u +at gives information as

A. velocity is a function of time.
B. velocity is a function of position.
C. position is a function of time.
D. position is a function of velocity and time.

xvii. The period of a vibrating body of frequency 100 Hz is

A. 100 second.
B. 10 second.
C. 0.1 second.
D. 0.01 second.

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xviii. Ohm is equivalent to

A. ampere/volt.

B. volt/ampere.

C. volt/coulomb.

D. coulomb/volt.

xix. An object moving in opposite direction to the gravitational force of the Earth is in

A. accelerated motion.

B. motion with constant velocity.

C. oscillations.

D. retarded motion.

xx. When the current through the coil of an electromagnet reverses, the

A. direction of magnetic field reverses.

B. direction of magnetic field remains unchanged.

C. magnetic field collapses.

D. magnetic field expands.

xxi. A periscope is an instrument used for

A. finding the focal length of a lens.

B. seeing very distant objects.

C. seeing very small objects.

D. viewing objects out of the line of vision.

xxii. Newton's law of gravitation applies to

A. small heavenly bodies only.

B. planets only.

C. both small and big heavenly bodies.

D. moons only.

xxiii. The sky appears blue because

A. that is its natural color.

B. the earth's atmosphere emits blue light.

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C. the air away from the sun cools down and turns blue.

D. the earth's atmosphere scatters more blue light than red.

xxiv. The dispersion of light when it passes through a prism shows that

A. the prism contains many narrow, equally spaced slits.

B. all colors in the light are treated the same.

C. different colors have different indices of refraction.

D. the speed of light in a vacuum is a constant.

xxv. Object W has a negative charge. Object W is repelled by object X. Object X is repelled by object Y and attracted to object Z. What are the charges on objects X, Y, & Z?

A. X, Y, & Z are all negative.

B. X & Y are negative, and Z is positive.

C. X is negative, and Y & Z are positive.

D. X & Z are positive, and Y is negative

b. *Match each item under Column A with the most appropriate item in Column B. Rewrite the correct matching pairs in the answer sheet provided.* [5]

| Column A | Column B |
|---|---|
| 1. Kinematics | (a) Tendency of fluids to make body sink. |
| 2. Buoyancy | (b) Direction of induced current. |
| 3. Increase in area | (c) Direction of induced magnetic field. |
| 4. Lenz's law | (d) Tendency of fluids to make body float. |
| 5. Optical fibre | (e) Study of moving bodies. |
| | (f) Total internal reflection. |
| | (g) Easily breakable. |
| | (h) Superficial expansion. |
| | (i) Cubical expansion. |

c. *Fill in the blanks by writing suitable word(s).* [5]

i. Tika measured the distance between two consecutive crests to measure the wavelength of a wave. The type of wave that he was measuring the wavelength is a _______________ wave.

ii. The direction of flow of electrons is opposite to the direction of ____________ in a conductor.

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iii. Water is used as coolant in car radiators because it has high __________.

iv. The centre of gravity of the displaced liquid is called ______________.

v. While launching a rocket, the burning of the fuel pushes the rocket up into its orbit. This action of the rocket is best described by ______________ law.

d. ***State whether the following statements are 'True' or 'False' and correct the false statements:*** [5]

i. The circular movement of a body is called rectilinear motion.

ii. The density of water at $4^0C$ is 1000 $gcm^{-3}$.

iii. The amount of heat required to convert unit mass of a substance from its solid state to liquid state without change in temperature is called specific latent heat of vaporization.

iv. The force experienced by a moving charged particle in a magnetic field is known as Newton's force.

v. The bending of waves when they travel from one medium to another of different densities is called reflection of waves.

e. *Answer the following questions:*

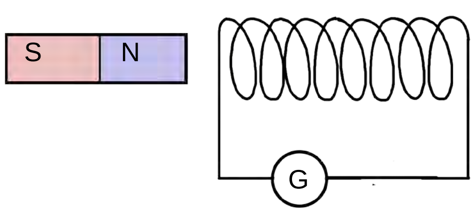
i. A tourist guide uses binoculars during his bird watching expedition but astronomer uses telescope to study the heavenly bodies. How are these two instruments different? [2]

ii. How much time does a bike with an acceleration of 2 $ms^{-2}$ take to increase its velocity from 10 $ms^{-1}$ to 30 $ms^{-1}$? [2]

iii. What do you mean by the statement 'relative density of gold is 19.3'? [1]

iv. Explain why both ends of the bridges are usually not fixed? [2]

v. In the diagram given below, what happens to the galvanometer pointer when




(a.) the magnet is moved near or away from the coil? [1]

(b.) the coil is moved near or away from the magnet? [1]

(c.) both the coil and magnet are moved in the same direction at the same speed? [1]

## SECTION B (50 Marks)

*Attempt only **five** questions.*

### Question 2

a. On Sital's birthday she was presented with a sparkling diamond ring. Explain property of light that makes diamond sparkle. [2]

b. The alternating current in our houses and schools keep on fluctuating between a minimum value and a maximum value. But we do not observe these fluctuations in the brightness of bulbs. Explain why? [2]

c. Define the following:

i. specific heat capacity,

ii. electric current and

iii. refractive index of a medium. [3]

d. Logs sometimes float vertically in a lake because one end has become water-logged and denser than the other. What is the average density of a uniform-diameter log that floats with 20.0% of its length above water? [3]

### Question 3

a. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 $ms^{-2}$, with what velocity will it strike the ground? After what time interval will it strike the ground? [2]

b. Give reasons for the following: [5]

i. Sounds are heard clearly at night than the day.

ii. Rainbows are formed only in presences of rain and sunlight.

iii. Repulsion is a surer test of presence of electric charge than attraction.

iv. It is cooler in the ground floor than on the first or second floors of a building, during summers.

v. Cutting is easier with sharp tools.

c. How much heat is necessary to warm 500 g of water from 20°C to 65°C? [2]

d. Describe wormhole. [1]

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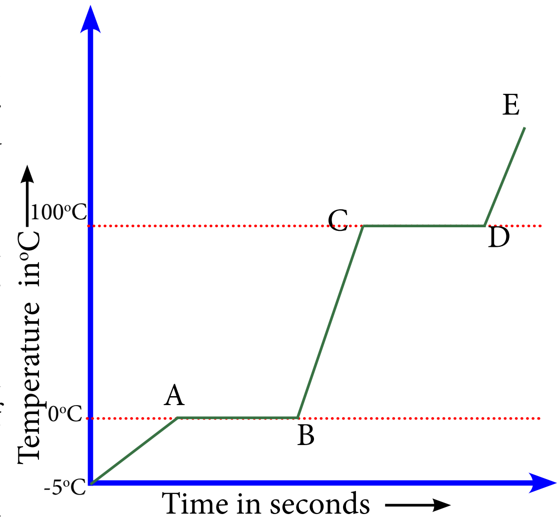
**Question 4**

a. The graph given aside represents the rise in the temperature of water with time as the heat is continuously supplied to it. [4]



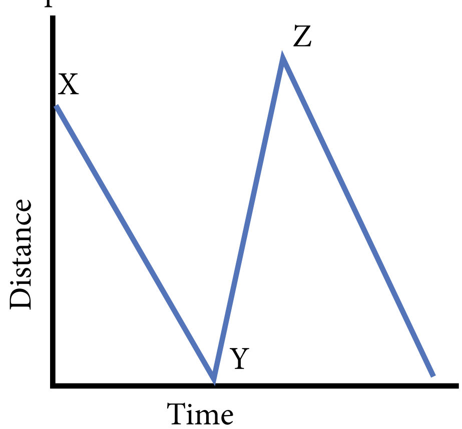

i. Name the phenomenon represented by the part AB of the graph.

ii. Name the phenomenon represented by the part CD of the graph.

iii. Why are these two parts AB and CD flat in the graph?

iv. Why is the part CD longer than the part AB?

b. Write a brief description that best suits the motion shown in the graph below. [2]




c. A couple of ice cubes floats in a glass of water. Will the water level in the glass change when the ice cubes have melted? Explain your answer. [2]

d. Why is a gold leaf electroscope enclosed inside a case? [2]

**Question 5**

a. Differentiate between:

i. Inferior mirage and Superior mirage. [2]

ii. Transverse waves and Longitudinal waves. [2]

b. Karma hears thunder 4 seconds after he sees lightning. How far from Karma has the lightning taken place? Take the velocity of sound in air as 340 m/s. [2]

c. Draw symbols for alternating current source and direct current source. [2]

d. Will the phenomenon of total internal reflection take place, when the light travels from rarer medium to denser medium? Give reason to support your answer. [2]

**Question 6**

a. What are electromagnetic waves? Give two examples of these waves. [2]

b. Explain a method of finding the location of a planet from the Earth. [2]

c. Sonam, Tandin, Dorji and Wangmo are runners in a 400 m race. The track is elliptical in shape and is marked with lime on a soccer field. Dorji completes his race in 55 s, Wangmo in 68 s, Sonam in 65 s and Tandin in 70 s. What is the velocity of the winner in the race? [2]

d. A cork weighs 2.5 gf in air. When tied to a sinker, the combination is found to weigh 20 gf in water. The sinker alone weighs 25 gf in water.

   i. Find the density of the cork. [3]

   ii. State the SI unit of density. [1]

**Question 7**

a. 3 kg of water at 80˚C is added to 8 kg of water at 25˚C. Find the temperature of the final mixture provided there is no loss of heat to the surrounding. The specific heat capacity of water is 4200 J/kg˚C. [3]

b. Why are small gaps left in between the rails of a railway line? [2]

c. Classify the following situations as examples of Newton's first law, second law and third law. Then explain your answer to support their classification. [3]

   i. Pushing a child on a swing is much easier than an adult on it.

   ii. A person pulls a table cloth swiftly and plates and mugs remains on the table.

   iii. A ball moves fast if kicked hard.

d. Express -270 ˚C in ˚F. [2]

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## Glossary

| | |
|---|---|
| **Acceleration** | The rate of change of velocity. |
| **Altimeter** | An instrument for measuring altitude. |
| **Amber** | Hard translucent yellowish-brown substance formed from resins of some trees and is used in jewellery. |
| **Aneroid barometer** | An instrument used to measure atmospheric pressure. |
| **Archimedes' Principle** | The law that states that when a body is immersed partially or wholly in a fluid (liquid or gases), it experiences an upthrust which is equal to the weight of liquid displaced. |
| **Astronomy** | The study which deals with celestial objects, space, and the physical universe as a whole. |
| **Atmospheric pressure** | Pressure exerted by atmosphere on the surface of the Earth. |
| **Black hole** | A region of space having a gravitational field so intense that no matter or radiation can escape. |
| **Bolts** | Large metal pin with head and used to hold things together with nut. |
| **Bunsen burner** | Laboratory instrument with vertical tube burning mixture of air and gas to produce heat. |
| **Balanced Forces** | A pair of forces equal in magnitude and opposite in direction. |
| **Capillary tube** | A very thin and long glass tube. |
| **Cosmology** | The study of the origin, evolution, and eventual fate of the universe. |
| **CRO** | Abbreviation of cathode ray oscilloscope. It is an evacuated tube in which electrons are emitted continuously due to heat, used in television or computer screens to create images or texts. |
| **Curvilinear motion** | Circular motion. |
| **Centre of Buoyancy** | Centre of gravity of the displaced liquid. |
| **Centre of Gravity** | Point on a body through which the whole weight of a body is supposed to be acting. |
| **Density** | Ratio of the mass to the volume of a substance. |

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| **Endoscopy** | Medical examination of the hollow organs of the body. |
| **Fibre glass** | Textile fabrics made from woven glass fibres. |
| **Fishplate** | Flat plate made of iron used for connecting railway rails. |
| **Hydrometer** | Instrument to measure the relative density of liquid directly. |
| **Inertia** | Tendency of body to remain in the state of rest or motion. |
| **Inertia of motion** | Tendency of body to remain in motion. |
| **Inertia of rest** | Tendency of body to remain at rest. |
| **Infra-red radiation** | An electromagnetic wave that produces heating effect on matter. |
| **Kinematics** | The science that deals with the study of moving bodies. |
| **LPG** | Abbreviation for liquefied petroleum gas. It is a mixture of hydrocarbons and it is used for cooking purposes. |
| **Magnification** | The action of magnifying something or the process of being magnified. |
| **Momentum** | The product of the mass and velocity of a moving body. |
| **Observatory** | A room or building housing an astronomical telescope or other scientific equipment for the study of natural phenomena. |
| **Pigment colours** | Natural colouring matter made from plants or animals. |
| **Rectifiers** | Device used to convert alternating current into direct current. |
| **Rectilinear motion** | Straight line motion. |
| **Relative Density** | Ratio of density of the substance to the density of water at $4^0$C. |
| **Solar System** | Collection of eight planets and their moons in orbit round the sun, together with asteroids, meteoroids, and comets. |
| **Submarine** | A ship which can operate below the surface of the sea. |
| **Sun dial** | An instrument showing the time by the shadow of a pointer |

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| | cast by the sun on to a plate marked with the hours of the day. |
| **Speed** | The distance travelled by a moving body in a given time. |
| **Telescope** | An optical instrument designed to make distant objects appear nearer, containing an arrangement of lenses, or of curved mirrors and lenses, by which rays of light are collected and focused and the resulting image magnified. |
| **Thrust** | The force that acts normally on a surface. |
| **Universe** | The system consisting of all the existing matter and space as a whole. |
| **Upthrust** | An upward force experienced by a body when immersed inside a fluid. |
| **Vacuum** | Empty space. |
| **Velocity** | The displacement traversed by a body in given time. |
| **Worm hole** | A wormhole is a theoretical passage through space-time that could create shortcuts for long journeys across the universe. |

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